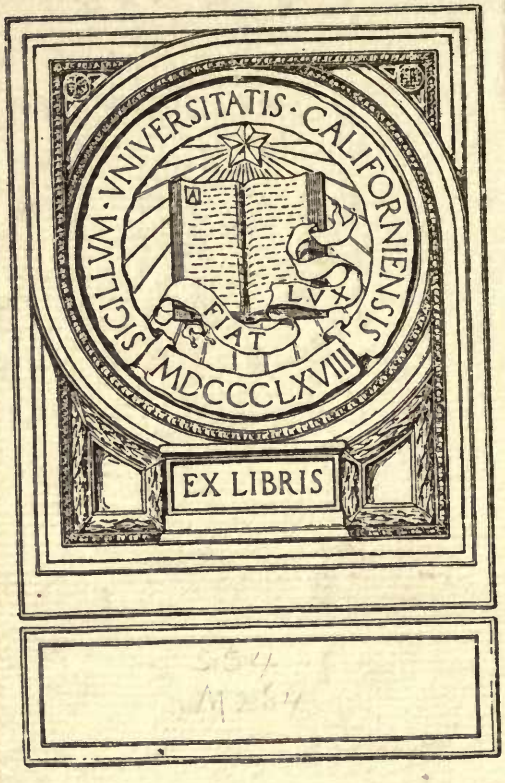
MINES AND THEIR STORY

BERNARD MANNIX


SIGILLVM · VNIVERSITATIS · CALIFORNIENSIS
LVX
FIAT
MDCCCLXVIII
EX LIBRIS

MINES AND THEIR STORY

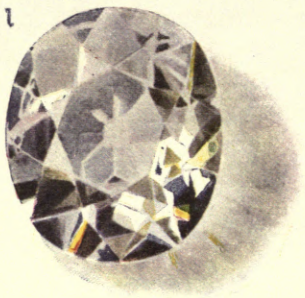
UNIFORM WITH THIS VOLUME

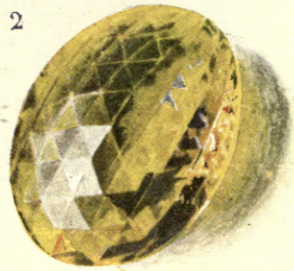
SAILING SHIPS AND THEIR STORY

By E. KEBLE CHATTERTON. With a Coloured Frontispiece by CHARLES DIXON, R.I., and over 130 Illustrations. Extra Royal 8vo, Designed Cover, in cloth gilt.

STEAM SHIPS AND THEIR STORY

By R. A. FLETCHER. With a Coloured Frontispiece by CHARLES DIXON, R.I., and 150 Illustrations. Extra Royal 8vo, over 400 pp. Designed Cover, cloth gilt.





FAMOUS DIAMONDS (Actual Sizes).

1. KOH-I-NOOR (102½ Carats). 2. AUSTRIAN ROSE (90 Carats).
3. BLUE HOPE (44½ Carats). 4. JACOB'S PLAYTHING, Uncut (21½ Carats). 5. GREEN SAXON (48½ Carats
6. PORTER RHODES, Uncut (150½ Carats). 7. TAVERNIER'S GREAT TABLE (242½ Carats).

MINES
AND THEIR STORY

BY

J. BERNARD MANNIX

UNIV. OF
CALIFORNIA

LONDON
SIDGWICK & JACKSON LTD
1913

TN147
M3

All rights reserved

UNIV. OF
CALIFORNIA

PREFACE

MAN learned to burrow probably before he was able to build, and almost as soon as he learned to love ornament or to hoard wealth, which was very early in his history. He soon wanted metal—bronze or iron for his weapons, copper for his ornaments, silver and gold for his wealth, and discovered that they were to be found more often beneath than on the surface of the ground. Of these early gropings many traces are still extant, and they form the beginnings of the long and eventful story of the mines—a story which has grown in scope, complexity, and sheer human interest from those early days until the present time.

Most of us, on those rare occasions when we give such things as mines a passing thought, imagine deep holes in the earth into which men descend, and from which, in some mysterious fashion, they procure supplies of coal, iron, gold, and other useful or valuable commodities. To many the mere contemplation of these profound pits, into which the light of day never enters, is repellent. Certainly a less congenial field for human labour could hardly be imagined, and the story of the mines is one long record of the adaptability of man to extraordinary conditions. It is this element of human endeavour that gives the story of the mines its chief interest and attraction, its unity of theme amidst apparent diversity of subject. It was this aspect which originally attracted the writer and led him to conclude, with a confidence which he trusts will not be misplaced, that the subject might be made interesting to the general and non-technical reader.

That the subject is one of considerable magnitude and importance will be readily admitted when it is recalled that we secure from the mines untold wealth in precious stones and precious

324494

metals, the baser metals with their myriad uses, and all the minerals, chief of which is coal, the world's main source of energy, as expressed in power, artificial light, and heat. It is a far cry from the diamond, the "gem of purest ray serene"—through the gold and silver of commerce and the arts, and the baser metals used in making machinery, tools, implements and utensils, and the thousand and one things used in an age of steel in a world encircled by telegraph wires, railway lines, and iron steamers—to a piece of coal, though the difference is more apparent than real. The diamond differs from the coal only in degree, not in kind, and all these varied products are alike derived from mines.

The mineral wealth that lies buried in the bowels of the earth has, too, played no small part in the history of the human race and in shaping the destiny of nations. It is no part of my purpose to discuss the elements that constitute value, but clearly it was in the nature of things that commodities which appealed so strongly to man's love of the rare, the beautiful, and the durable, as the precious stones and the precious metals, should be esteemed and desired. They coloured the thoughts, enriched the symbolism, and influenced the conduct of mankind. And as the sense of possession and of property developed, these symbols of wealth were undoubtedly responsible for much cupidity and covetousness, on the part of nations as well as of individuals. Just as individuals coveted one another's gold, so one community would cast envious eyes on the mines or the treasures of another. History is full of examples: it is one long record of plundering expeditions having for their avowed or tacit object, or as an inevitable sequel, the conquest of a country endowed with mines of the precious metals or rich in treasures of gold or silver specie or bullion. Numerous instances will doubtless occur to the reader. In the great conquering expeditions of Darius and Alexander the removal of the loot of empires played a prominent part. The Punic Wars arose out of the Roman desire to wrest the mines of Iberia from the hands of the Carthaginians. The procuring of gold and silver was the openly avowed object of the conquest of Mexico by Cortes, of Peru by Pizarro, and in fact of the New World generally by the nations of the Old. And

in these latter days the same thing holds good. Human nature changes but little in the course of the ages. Men still fight, but about different things. In this age of industry not only gold but also iron and coal have become precious. Their possession makes a nation wealthy and powerful or perchance attracts the unwelcome attentions of a still stronger Power.

Those parts of the story of the mines which treat of their discovery, their development, and the lives, manners, and customs of the miners, will be found to be by no means uninteresting. In the course of the narrative we discover unsuspected forces in the evolution of society—human motives hitherto but dimly realized. Then there remains to consider the physical devastation to which mining has subjected many countries, scarring the face of the earth, changing the courses of rivers with its debris, demolishing the trees for fuel and timbering. But above and beyond the historical or merely physical aspects of this endless quest for the precious metals in which whole races have been exterminated, nations have been subjugated, and even civilizations have been destroyed, there are the great ethical questions of the effects of the discovery of the precious metals on mankind, and the economic question of whether even gold-mining is on the whole profitable to the community. But such problems are so vast as to be outside the purview of this volume.

As we follow the annals of mining, it becomes evident that our knowledge of the distribution of minerals has only been gained by slow degrees—much of it quite accidentally, though in later years the researches of geologists have been of great assistance to the prospector. The series of lucky chances which have led to the location of valuable deposits forms one of the most romantic and fascinating aspects of the subject. The digging of a mill-race led to the rush for gold to California. Some of the richest silver-mines in Mexico and Peru were located by the accidental smelting of fragments of ore in casual camp fires, while the presence of silver in the great Silver Mountain of Potosi was revealed by the pulling up of a shrub by a native hunter. The immense deposit of silver ore at Broken Hill, N.S.W., was at first thought to be tin. Bodies

of iron ore have been frequently detected by the presence of traces of iron in adjacent springs and streams.

There are some features which the different kinds of mines and minerals have in common; although it is difficult even to generalize on the location of minerals without lapsing into technicalities. In mountainous districts the strata are frequently cut through and exposed by the streams that run down the hill-sides. In such districts, and more especially in those that have, like the valleys of Western America, been only partially explored, there are many explorers or prospectors who travel singly or in bands searching for traces of ore. They are generally experienced miners. Knowing that the most productive lodes run as a rule east and west, they pay special attention to the gorges and river valleys which cut the range. Some knowledge of geology is both valuable and essential to the prospector. He should know that the minerals, with few exceptions, are confined to the earth's older strata—from the New Red Sandstone downwards. These older rocks form the rugged and mountainous portions of the globe. The search for all metallic ores except those of iron is thus confined to hilly districts, and, as a rule, to the rocks lying below the coal measures. It is an interesting fact that among the better-known metals tin occupies the lowest position, being found in granite. Copper occupies the next zone in ascending order, and gold occurs a little higher. Silver is associated to some extent with both copper and gold in their particular geological horizons.

My choice of subjects requires little explanation and no apology. Gold and silver are the historic precious metals known to and valued by man, almost since the world began. Diamonds are of course, for value, purity, and brilliance, unique even among precious stones. Iron as a dominant factor in an age of steel is only equalled in importance by coal, which is not only an almost universal fuel, but the world's most potent source of energy, whether in the form of heat or light, or transformed into steam.

So much does man owe to what in Germany is called "The Robber Industry." He takes away the vast stores of minerals which a bountiful Nature has deposited, and leaves nothing in

their place. Sometimes he pays the penalty of his temerity with his life. Instances of the dangers of mining have been only too frequent in its annals. The bones of the prehistoric miner, crushed in his primitive working, are testimony as eloquent of the perils of his calling as the modern account of a mining disaster in which instances of heroism stand out vividly against a background of tragedy and gloom. It is on this note that the story of the mines should draw to a close. When next you think of the products of the mines think also that they should be valued not only according to their rarity, or the inhuman law of supply and demand, but also because they have cost men's lives.

And now there remains the duty, which is also a pleasure, of returning thanks to the many who have so kindly rendered me valuable assistance in the course of the preparation of this work. I am particularly anxious to acknowledge my indebtedness to Mr. T. A. O'Donahue, F.G.S., of the Valuation (Minerals) Department, Inland Revenue, Birmingham, for his ungrudging kindness in reading the MS. of the chapters relating to coal-mining, and in giving me the benefit of his expert knowledge and advice on that subject. For assistance in illustrating the book, my publishers and I alike are indebted to the courtesy of many mining companies and other firms. Interesting photographs have been supplied by Messrs. Wernher, Beit and Company, the Kalgoorlie Gold Mining Company, the Broken Hill Proprietary Company, the Taff Vale Railway Company, and the Wigan Coal and Iron Company; the last have also kindly lent some blocks. The Sandycroft Foundry Company, as well as the Taff Vale Railway Company, have permitted the inclusion of pictures of models belonging to them and deposited at the Science Museum, South Kensington. Acknowledgments are also due to Messrs. Cassell and Co.'s Pictorial Agency; to Messrs. Harper Bros., for Sir William Crookes' photographs of diamonds and the industry; and to Messrs. Crosby, Lockwood and Co., for a number of illustrations drawn from Davies' "Metalliferous Minerals and Mining," and Eissler's "Metallurgy of Gold" and "Metallurgy of Silver." Specific acknowledgments will be found in the List of Illustrations.

J. BERNARD MANNIX.

CONTENTS

		PAGE
PREFACE		v
	GOLD	
CHAPTER		
I.	THE GOLDEN DAWN	1
II.	THE CONQUISTADORES	14
III.	THE GREAT GOLD DIGGINGS	30
IV.	THE WORLD'S GREAT GOLD-MINES	52
V.	MODERN GOLD-MINING	74
VI.	LATER GOLD BOOMS	96
	DIAMONDS	
VII.	GEMS OF LONG AGO	107
VIII.	THE DIAMOND MINES OF SOUTH AFRICA	121
IX.	DIAMOND CUT DIAMONDS	146
	SILVER	
X.	SHEKELS OF SILVER	156
XI.	ARGENT AMERICA	167
XII.	OLD WORLD SILVER-MINES	187
XIII.	THE SILVER STATES	197

CONTENTS

COAL

CHAPTER		PAGE
XIV.	The Forest Primeval	221
XV.	Coals and Colliers of Yester-Year	230
XVI.	The World's Coal-fields	252
XVII.	Modern Mines and Miners	273

IRON

XVIII.	The Story of Iron	292
XIX.	A World-wide Ore	306
XX.	Iron-mining and the Age of Steel	321
INDEX		331

LIST OF ILLUSTRATIONS

PAGE

Coloured Plate of Diamonds *Facing title-page*
By permission of the Pictorial Agency.

Egyptian Ship laden with Gold: the Expedition to Punt *Facing* 6
From a wall-painting in the Temple of Deir-el-Bahri.

Coins of Greece and Asia Minor (4th Cent. B.C.) *Facing* 8
From originals in the British Museum.

Mexican Arrastra 17
From Eissler's "Metallurgy of Silver."

Mexican Mill 18
Drawn after John Miers' "Travels in Chile," 1826.

Trapiche at Lavaderos or Gold Washings 20
Drawn after John Miers' "Travels in Chile."

Primitive Mining 22
From Davies' "Metalliferous Minerals and Mining."

The Dredge "Gold Bank" *Facing* 38

Hydraulic Mining on the Georgetown Divide *Facing* 38
From Eissler's "Metallurgy of Gold."

Tailings Wheel, Ferreira Deep Mine *Facing* 40
By permission of Wernher, Beit & Co.

Section across Comstock Lode and Strata 42
From Davies (*ut sup.*).

Models of Level Timbering, Comstock Mine *Facing* 42
From a model at South Kensington.

LIST OF ILLUSTRATIONS

PAGE

Gibraltar Mine, Adelong, New South Wales — *Facing* 50
From Eissler's "Gold" (*ut sup.*).

Smelting Furnace, City and Suburban Mine — *Facing* 54

Cyanide and Slimes Works, City and Suburban Mine — *Facing* 54

The Compound, Glen Deep Mine — *Facing* 62

General View, Ferreira Deep Mine — *Facing* 62

General View, French Rand Mine — *Facing* 64

Battery, Crown Deep Mine — *Facing* 66

Extractor House and Slimes Works, Village Deep Mine — *Facing* 68

Descending Robinson Gold Mine — *Facing* 74
The last eight photographs by permission of Wernher, Beit & Co.

Section of Stopes in a Mine — 76
By permission of the Pictorial Agency.

Underground: City Deep Mine — *Facing* 76

Headgear, Village Deep Mine — *Facing* 78
By permission of Wernher, Beit & Co.

Model of Stamp Battery — *Facing* 78
From a model at South Kensington, by kind permission of the Sandycroft Foundry Co.

Old Cornish Stamp — 80
From Davies (*ut sup.*).

Agitating Gear, Robinson Gold Mine — *Facing* 80

Extractor House, Crown Deep Mine — *Facing* 82
By permission of Wernher, Beit & Co.

Revolving Screens or Trommels — 83

Round Buddle — *Facing* 84

Linkenbach Table — *Facing* 84

LIST OF ILLUSTRATIONS

		PAGE
Chlorination Vat The last four from Eissler's "Gold" (*ut sup.*).		86
Cyanide Plant: View and Elevator From Davies (*ut sup.*).	*Facing*	86
Hydraulicking Auriferous Gravel into Sump	*Facing*	88
Barge for Hydraulicking, fully equipped	*Facing*	92
Hydraulicking Barge, ready for towing The last three from Eissler's "Gold" (*ut sup.*).	*Facing*	94
Kalgoorlie Mine: South Drive, 1,050-foot level By kind permission of the Kalgoorlie Gold Mining Co.	*Facing*	98
General View, De Beers Diamond Mines, Kimberley By permission of the Pictorial Agency.	*Facing*	124
De Beers Washing and Concentrating Machinery	*Facing*	136
The "Pipe," Kimberley Mine	*Facing*	136
River Washings at Klipdam The last three from Sir W. Crookes' "Diamonds."	*Facing*	136
Searching Tables, De Beers Mines, Kimberley By permission of the Pictorial Agency.	*Facing*	140
Underground Workings, De Beers Mine	*Facing*	144
The Cullinan Diamond (natural size)	*Facing*	144
A Group of Historic Diamonds The last three from Sir W. Crookes' "Diamonds."	*Facing*	152
Grinding Mills in Shed Drawn after a contemporary print.		173
Patio, or Amalgamating Floor		174
Furnace for reducing Silver, Chile Both drawn after Miers' "Travels" (*ut sup.*)		176
Silver Ore Strata, Sta. Rosa, Peru From Davies (*ut sup.*).		179

LIST OF ILLUSTRATIONS

PAGE

Stamping Mill, Chile 184
Drawn after Miers' "Travels" (*ut sup.*).

Cross Section, Simon Judas Mine, Banat 189

Section across Erzgebirge 192

Silver Fahlbands at Kongsberg 194

Longitudinal Section across Comstock Lode 199
The last four from Davies (*ut sup.*).

Section of Silver Mill *Facing* 200

Combination Pan 202

Stetefeldt Roasting Furnace 204

Pan Room, Consolidated Virginia Mine *Facing* 204
The last four from Eissler's "Silver" (*ut sup.*).

Structure of Ruby Hill 206
From Davies (*ut sup.*).

General View, Smelting Works and Refinery, Broken Hill Mine *Facing* 214

Mechanical Feed of Ore to Blast Furnaces *Facing* 214

Traverse carrying Loaded Trucks to Discharge *Facing* 216

Weighing Charge into Trucks from Storage-bins *Facing* 216

Feed-floor of Furnaces: Trucks discharging *Facing* 218

Pressed Zinc-Silver Alloy on Floor *Facing* 218
The last six by kind permission of the Broken Hill Proprietary Co., Ltd.

Calamites 224

Lepidodendron 225
From drawings by Herbert Green.

Model of Pit-head Gear *Facing* 234
From a model at South Kensington.

LIST OF ILLUSTRATIONS

PAGE

Shaft and Cages *Facing* 234
From a model of 1835 at South Kensington

Mine-surveying in the Middle Ages 241
From Gregorius Agricola, *De re Metallica*, 1556.

Pumping Machine of 1684: Welsh Coal-mine 243
From a contemporary MS.

Pit-screens: Screening and Cleaning Fuel *Facing* 246
From a photograph, by courtesy of the Wigan Coal and Iron Co.

Miners' Safety Lamps *Facing* 250
From a group of original lamps at South Kensington.

Pit Head, Clock Face Colliery, near St. Helens *Facing* 256
From a photograph, by courtesy of the Wigan Coal and Iron Co.

Model of Shaft Tubbing and Cage *Facing* 272
From a model at South Kensington.

Shaft-sinking, Kind-Chaudron method 274

Plan showing Shaft-pillar 276

Coal-getting: at the Bottom of the Shaft *Facing* 276

Coal-getting: Colliers "holing" *Facing* 280

Cleaning Fuel *Facing* 282

Screening and Sorting Fuel *Facing* 282
The last four from photographs by Mr. James McGowan, by the courtesy of the Wigan Coal and Iron Co.

Model of Coal-tip, with Anti-breakage Box (1896) *Facing* 286
From a model at South Kensington, by permission of the Taff Vale Railway Co.

Four Coal-tips at Work, Penarth Dock *Facing* 288

Plan of Anti-breakage Box for Coaling *Facing* 290
From photographs, by courtesy of the Taff Vale Railway Co.

English Iron-workers, *c.* 1350 301
From a contemporary MS. in the Bodleian Library.

LIST OF ILLUSTRATIONS

PAGE

Sectional Model of Blast-furnace *Facing* 304
From a model at South Kensington.

Steel-works: Metal Mixer (capacity 250 tons) *Facing* 312
From a photograph, by courtesy of the Wigan Coal and Iron Co.

Geological Position of Iron Ores of Lake Superior 318

Section of Hæmatite Deposit at Parkside, Cumberland 322
From Davies (*ut sup.*).

Blast-furnace, Kirkless Iron and Steel Works *Facing* 324

Steel-works: Fourteen-inch Rolling Mill *Facing* 328
From photographs, by courtesy of the Wigan Coal and Iron Co.

UNIV. OF CALIFORNIA

MINES AND THEIR STORY

GOLD

CHAPTER I

THE GOLDEN DAWN

GOLD! The very name concentrates and visualizes in one word much of the drama of human history, and of the motives that have animated men. Its story is a world-old romance as yet unfinished, and its symbolism is to be found throughout the whole range of literature. One of the earliest known of the precious metals, it was for long the rarest, and is still the most valuable in anything like general use. That a substance so unique in the richness and beauty of its warm yellow colouring, so unsullied and undimmable in its brightness, so unchanging in its imperishability, should be valued and desired by men, was natural and inevitable. Did not the Psalmist say, "More to be desired . . . than gold, yea, than much fine gold"? And as it came to be used more and more, first for personal ornaments, then for idols

—such as those of Belus in Babylon and Apollo at Delphi—and for decoration and purposes of display, the beauty of it and the love of it began to dominate men's minds and give colour to their thoughts, so that gold and the symbolism of gold played no small part in oral legends and written literatures. Even to this day we apply the word "golden" to something precious and pure. We can find no term more worthy of the light of the sun than the "golden" sunshine. And when we speak of the Rome of Cicero, Cæsar, and Virgil, or the England of Elizabeth, we can find no words more glowing or more eulogistic than Milton's "age of gold."

On the desire for gold as a motive for human action a whole epic might be written. This desire for the yellow metal, whether for ornamental or æsthetic purposes, or—more especially since its first use as coinage—for its intrinsic value, is deep-rooted and universal. It is coveted both for itself and as the symbol of wealth and all the power that wealth implies. It is no marvel then that this gold-lust arouses some of the most primitive passions, alike in the individual and in the community. In wars and the campaigns of conquerors like Darius and Alexander the acquisition of the precious metals has always been something more than incidental.

If, then, all this holds good of gold in general, much of it is even more strikingly exemplified in the story of the world's gold-mines. Wars have been waged for the possession of gold-mining countries, as history repeatedly proves, from the time of the Punic wars onwards. The golden lure has attracted men to the wild places and among the wild people of the earth, and the excitement of easily won wealth and the absence of social restraints has almost invariably led to a good deal of tyranny, injustice, lawlessness, and crime. Justin, writing in the third century of the Christian

era, asserts that the natives of Lydia, one of the earliest of gold-mining countries, were habituated to indolence, gaming, and licentiousness. The later history of the gold-fields tends to confirm the probability of this account.

One is naturally impelled to proceed to some consideration of the social influence of the gold-mines, their effect on industry and commerce generally, the question whether on the whole even gold-mining is really a profitable proposition, and finally, if the procuring of gold is a commercial necessity, its moral effect is not in the main anything but good. The necessary limitations of a volume such as this, however, preclude the discussion of any social, economic, or ethical questions of such magnitude.

The story of the gold-mines is by no means a wholly sombre one. Many Argonauts, ancient and modern, have gone out into the unknown, and, after enduring hardship and exile, have found wealth under circumstances as romantic as described in any story that was ever written. There has been always something exceptionally alluring about the gold-fields, something particularly fascinating in gold-seeking. From time immemorial a sort of halo of romance has hovered over the Argonaut, and even to-day many have a hazy notion that the gold-digger proceeds to a sort of Tom Tiddler's ground and merely picks up nuggets. How far such ideas are removed from the actual facts, how much of hardship and adventure there is in the quest of the modern Jason, and still how much there is that is picturesque and interesting in the story of the gold-mines, it is part of my purpose to show.

In its pure state, gold, as used by the ancients, is the most malleable and ductile of metals. In modern times it has been beaten out into leaves so thin that it would require many thousands to make the thickness

of a single inch. A mere grain of gold can be beaten out into a sheet with an area of 54 square inches, or drawn into a golden wire 167 yards long. It is so malleable that it can be welded cold.

Gold occurs most frequently in its native or metallic state. It is found in many forms, and chiefly in two widely differing conditions. It has been discovered from time immemorial in grains distributed in drifts of gravel, sand, and clay in valleys, in the beds of rivers, or among boulders that have been weathered and worn down from the mountains in the course of ages. Although this is the oldest form in which the precious metal has been known to man—probably all the gold of ancient times being derived from such alluvial workings—it is the newest source, geologically speaking.

The second and really the oldest resting-place of gold is in the lodes and veins, generally filled with quartz, that traverse the older slaty rocks, principally those of Cambrian and Laurentian age. It is found, too, finely disseminated in rocks of a granular structure. Gold-seekers have gradually followed the traces of the yellow metal up the mountain sides until they have discovered, in veins and lodes, some of the sources whence the alluvial gold has been derived.

Among the quartz and other rocks the gold has been found in various forms—in grains and plates, in hair-like fibres, in tree-like incrustations, or in sponge-like masses, as among the telluride ores of Western Australia. There too it has been found in the extremely rare crystallized state. But it is only in modern times that the precious metal has been worked in the solid rock. Down through the centuries man has been content to gather the gleanings of the golden harvest that nature has so lavishly scattered broadcast through the world.

THE GOLDEN DAWN

The beginning of the history of gold is usually assigned to Greece and to a period about the ninth century before the Christian era, but there is reason to believe that its use was more widespread at a very much more remote period of the past. In the Egyptian code of Menes,* which is said to date from about 3000 B.C., there is a reference to the ratio of value between gold and silver, which goes to prove that both the precious metals were in use at a very early period in the history of that wonderful country.

The earliest definite mention of gold-mining extant in the whole range of Occidental history is the story of Cadmus the Phœnician, who, according to Strabo, about the year 1594 B.C. opened a gold-mine in Thrace and carried thither many of the adjuncts of civilization. Strabo also mentions deposits in Armenia and Macedonia.

In the Egyptian expedition to Punt (1503–1481 B.C.) we have further evidence of the antiquity of the use of the yellow metal. The story of the expedition to Punt—the site of which has been the subject of much controversy, but is now generally accepted as having been in Somaliland—is graphically depicted on the walls of the temple of Deir-el-Bahri near Thebes. Among the cargo with which the ships of the Queen Hatshepsut's expedition were laden were bags of gold.

The famous Greek legend of Jason and his quest for the Golden Fleece is the classic of gold-lore, and has conferred the title of Argonauts on seekers after the precious metal for all time. This story of the band of heroes who sailed in the fifty-oared barge or argosy under the command of Jason, to Colchis on the Euxine, is of great antiquity. Homer mentions the *Argo*, and Pindar in the fourth Pythian ode gives the oldest detailed account of the voyage. In ancient times the

* Wilkinson's "Ancient Egyptians," II. 241.

expedition was regarded as a historical episode marking the opening up of the Euxine to Greek commerce. Its object, stripped of its poetic symbolism, was undoubtedly the acquisition of gold, which was secured by the inhabitants of Colchis in fleeces or sheepskins as it was washed down the rivers.

The whereabouts of ancient Ophir mentioned by Solomon (*circa* 1000 B.C.) is uncertain, and has been the subject of much conjecture and controversy. Sheba certainly was a region of Arabia, and it is coupled with Ophir in Genesis x., but the exact location of the golden Ophir of Solomon's time is lost in the mists of antiquity.

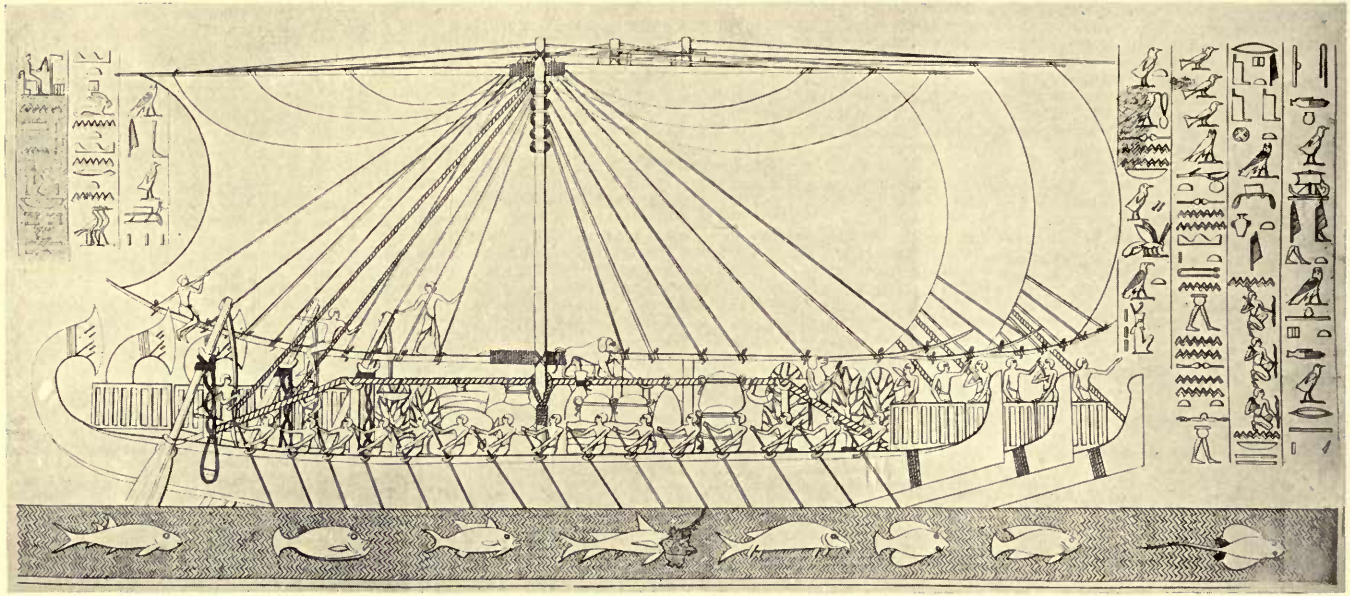
It is however fairly certain that so early as the twelfth or fourteenth century B.C., gold, and even gold currency, was in fairly general use in the various civilized nations between Egypt and India.

Of the fabled wealth of Ind and its people, Pliny wrote: "The Dardaneans inhabit a country the richest of all India in gold mines. . . . In the country of the Naræans, on the other side of the mountain Capitalia (Vindhya ?), there is a very great number of mines, both of gold and silver, in which the Indians work very extensively. . . . Just within the mouth of the River Indus there are two islands named Chryse and Argyre, so called, as I think, from the mines of gold and silver which are found there; for I cannot believe, what some have asserted, that the soil on them consists wholly of these metals." There were also placer and quartz mines in Arabia at a very remote period.*

The famous auriferous sands of the Pactolus—now the Sarabat, which flows out near modern Smyrna, were worked by the Phrygians, probably from the twelfth to the fifth century B.C. Herodotus † asserted

* "The Gold Mines of the Land of Midian," Captain Burton.

† III. *cap.* 26, 27.



6] EGYPTIAN SHIP LADEN WITH GOLD: THE EXPEDITION TO PUNT.

that Pytheus procured gold from the workings so late as 470 B.C. These gold-bearing sands, or "placers" as we call them nowadays, were the source of the fabulous wealth of Crœsus, Midas, and Pytheus. The last-named, in his greed for gold, condemned vast numbers of his own subjects to the mines or gold-workings.

The Phœnicians worked the gold "placers" of the Tartessus, now the Guadalquivir, in Iberia. Beginning about the eleventh century B.C., these auriferous beds were worked for several centuries, but latterly the output dwindled to trifling dimensions. With the working out of these "placers," about the fifth century B.C., the auriferous exhaustion of Phrygia and Iberia may be said to have been, for the time at least, complete. Then followed a dearth of the precious metals in the countries bordering the Mediterranean. A contributory cause was of course the defeat of the Lydians under Crœsus and the looting of Sardis and all Asia Minor by Cyrus. Cambyses added the gold of Egypt to the Persian hoard, and Darius laid the frontier nations of India under tribute. In all probability a large portion of the Persian booty found its way back to Europe in the train of the victorious Alexander, when he conquered Persia and the adjoining countries. Some idea of the value of this loot may be gleaned from Plutarch's estimate that it required 10,000 teams of mules and 500 camels to transport it to Susa. Other authorities place the value at (approximately) the equivalent of £32,000,000 sterling, besides what was brought from Bactria and Egypt.

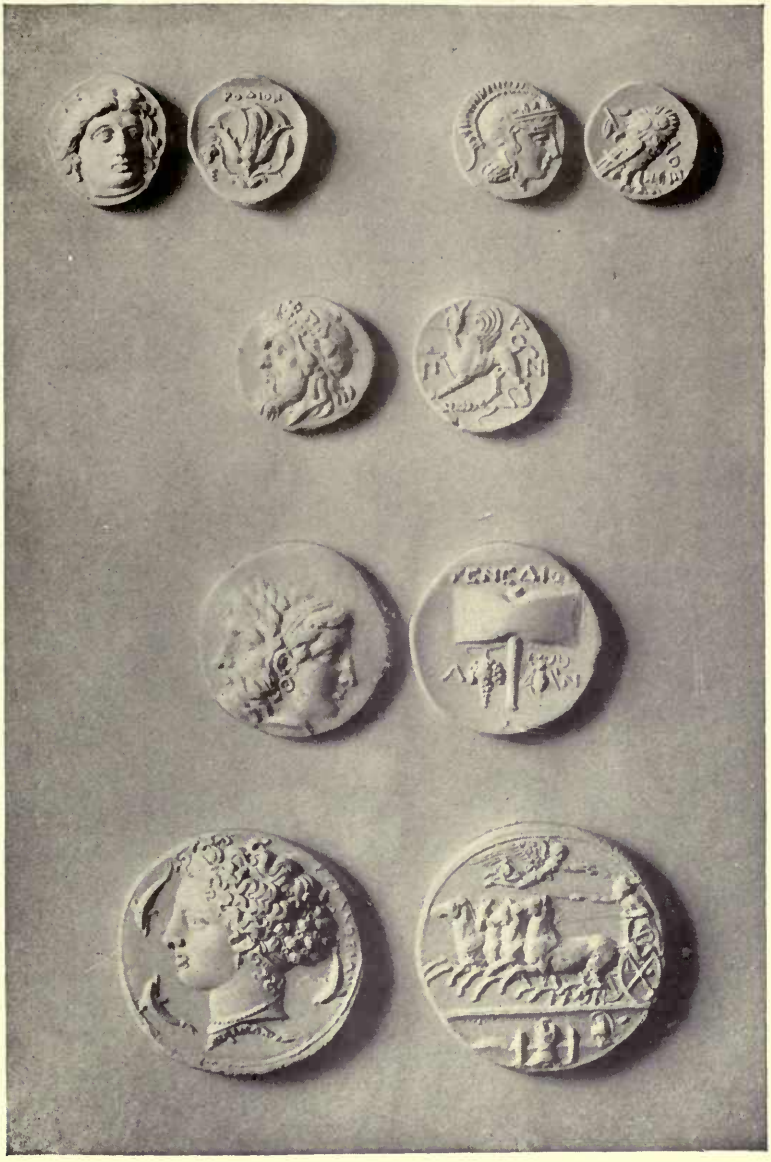
It was during the period between these two epoch-making expeditions led by Darius and Alexander that the scarcity of gold led the ancients to search among rocks for the precious metal. To this period the earliest efforts of the primitive quartz-mining of the ancients may be traced, in Bactria, Egypt, and Greece.

The aborigines of Bactria had, prior to the desolating conquest of that region by the Tartars (*circa* 150 B.C.), long worked the Siberian gold-beds, and this although they were ignorant of the use of iron for tools. Gmelin, who visited the Siberian mines between 1733 and 1743, and inspected what remained of the ancient workings, wrote that the aborigines must have excavated the subterranean passages with almost incredibly arduous labour. They had no better tools than copper hammers and wedges. The passages were so narrow that the workmen must have crawled on their stomachs to reach the quartz, from which they picked out the thin filaments of native or pure gold with the sharpened fangs of boars. It is not known how they obtained light, and there can have been no attempt at ventilation. The slightest mishap to the supports of the workings must have resulted in the unfortunate miner being crushed to death. That some such fatalities must have occurred is evident from the fact that in the debris of some of the ruined workings human skeletons have been found—sad relics of some of the world's earliest victims in the quest for gold.

Of the mines of Samos, Theophrastus wrote about 240 B.C.: "Those who dig in the mines cannot stand upright at their work, but are obliged to lie down, either on their back or on their side; for the vein of earth they dig runs lengthwise and is only of the depth of two feet, though considerably more in breadth, and it is enclosed on every side with hard rock from which the ore is drawn forth."

Before the dawn of the Christian era, gold-mining in Egypt had become a comparatively highly organized industry. Diodorus, who visited the country about 50 B.C., thus describes some of the gold-mining methods pursued in that country: "On the confines of Egypt and the neighbouring countries there are parts full of gold-

UNIV. OF
CALIFORNIA



Coins of Greece and Asia Minor.
(Fourth Century B.C.)

mines, whence, with the cost and pain of many labourers, much gold is dug. The soil is naturally black, but in the body of the earth there are many veins, shining with white marble and glittering with all sorts of bright metals, out of which those appointed to be overseers cause the gold to be dug by the labour of a vast multitude of people."

Diodorus goes on to describe how the aid of fire was introduced to facilitate the work of cutting through the rocks in search of the veins of precious metals. He proceeds: "After thus being able to reach the ores, the workmen had still to contend with the obstacles of subterranean water, of unwholesome air, of the filling of the pits and passages by the earth giving way, and the darkness of the mines." We do not know what precautions were adopted to obviate the dangers of water and foul air, but the roofs of the mines were supported by large pillars being left of the natural rock. This, as we shall see, is a method that is pursued down to the present day. In some parts too the loose stones were prevented from falling by masonry. At first the only light in the mines was obtained by burning chips of fir-wood; but at length lamps were invented, which are described by a later writer, Clemens Alexandrinus. In a similar fashion to many of the miners of to-day, each man had a little oil-lamp fixed on his forehead, which turned on a movable base somewhat after the style of a compass. The passages were entered, not by perpendicular shafts, but by means of galleries, or adits as we call them now, from the side of the mountain. The ore was brought out on the backs of slaves, who alone were employed in the mines of ancient Egypt, which lay in all probability in the mountains between the Nile and the Red Sea.

The greater portion of the world's supply of the precious metals in classic times was derived from the

mines of Iberia (Spain). They were first worked by the Carthaginians (480–206 B.C.), who, with their disciplined troops and superior weapons, easily conquered the aborigines of the Iberian peninsula. The natives were reduced to slavery and compelled to dig in the earth for gold and silver.

"These people," wrote Diodorus, referring to the unfortunate Iberians, "though by their labour they enriched their masters to an incredible extent, did it by toiling night and day in their golden prisons. They were compelled by the lash to work so incessantly that they died of the hardships in the caverns they had dug." The excessive mortality in the mines caused a scarcity of native labour, and this was made good by the importation of slaves from Africa. Such was the beginning of the slave traffic on a large scale in Western civilisation—so that we see that the mines are to some extent responsible for initiating this infamous traffic in flesh and blood. Slave labour largely augmented the output of the Iberian mines, and exercised a great influence on the commerce of the ancient world.

The appearance of Carthaginian gold and silver in Italy roused the cupidity of the Romans, and undoubtedly led to the first Punic War (264–241 B.C.), by which Rome secured Sicily, Sardinia, and Corsica—mining countries all. In the year 238 B.C. Hamilcar Barca conducted a marauding expedition through Iberia, and sought to justify his conduct to the Carthaginians by asserting that it was necessary to acquire new mining territory in order to counterbalance the loss of the mines of the Italian islands. The year 209 B.C. saw the death of Hamilcar, who bequeathed the command of his forces to his son Hannibal. Hannibal, still without authority from the Punic government, proceeded further to ravage the Iberian hinterland and discovered more mines.

Eventually the capture of Sagentum, and the growing demand for the precious metals for her new coinage, led Rome to embark on the second Punic war. Beginning in 219 B.C., this campaign, as we know, was conducted almost entirely in Spain, and ended in its conquest by Rome under Scipio (207 B.C.) and its final evacuation by the Carthaginians.

Historians tell us that the gold of the Iberian mines, and the sybaritic love of wealth and luxury and ease which it fostered in the Carthaginians, led to the decline and fall of Carthage before the more vigorous legions of Rome. "Rome trusted to itself and its sword," wrote Heeren; * "Carthage to its gold and its mercenaries. The greatness of Rome was founded upon rock; that of Carthage upon sand and gold-dust."

The Spanish mines were undoubtedly rich at this period. The yield of gold was unprecedented, as witness Pliny, who wrote: "Some have related that Asturias, Galicia, and Lusitania furnish two thousand pounds of gold annually; but Asturias supplies the most; nor in any other part of the world during so many ages has so great a quantity been obtained."

But even the pride and pomp and glory of Imperial Rome were destined to share the fate of Carthage. Again, as invariably and inevitably happens, gold fostered luxury and extravagance, which, combined with over-taxation, brought social and economic ruin. Then came the irruptions of the Vandals. The Roman legions were driven southwards into Italy itself. Territory and revenues were alike lost, and with the mines of Spain and Hungary the sources of the supplies of the precious metals.

During the turbulent centuries that followed, mining shared the fate of other industries amidst the commercial insecurity and general chaos, and little trace

* "Researches, African Nations," vol. I. p. 285.

of any working of the precious metals can be found until about the eighth century of the Christian era. Then the Rothausberg mine, which had been worked by the Romans, was once again opened. Gold-mining was begun at Kremnitz and in the Farebajer mountains in Hungary, where extensive remains of these ancient workings have been found. The gold- and silver-mines of Altenburg in Hungary, and of Salzburg in Austria, were productive about the fifteenth century. There was also a limited amount of gold procured during the Middle Ages from alluvial washing. The sands of the Rhine, chiefly between Strasburg and Philipsburg, were worked for gold, the Strasburg magistrates at one time farming out the right to work them.

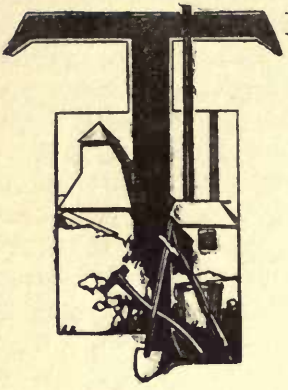
Nor did the quest for gold in Spain, which had gone on so long under its Carthaginian and Roman masters, cease after the Saracenic conquest. The auriferous sands of the Tagus, the Douro, and the Guadalquivir were eagerly searched by the Moorish gold-seekers. During the centuries of their occupation of Spain the Arabs pursued their search for the precious metals with great vigour. The Spanish mines continued to furnish, as of old, the world's chief supplies of gold. The Moors worked the mines at Lares and Jaen, and near this latter place the hills were honeycombed with some 5,000 shallow pits.

Jacob in his "History of the Precious Metals" remarks that, from the fall of the Roman Empire to the discovery of America, "the precious metals were sought, not by exploring the bowels of the earth, but by the more summary process of conquest, tribute, and plunder." Without going so far as Del Mar, who holds that this generalisation may be applied not only to the Middle Ages but (with slight exception) to the whole period from the Commonwealth of Rome to the discovery of gold in California, it may be accepted as virtually true

that during the greater part of the Middle Ages there was little or no mining of the precious metals. The world's stock of gold was to all intents and purposes stationary—if not actually diminishing—for many centuries, until the discovery of America opened up a new and, as it proved, a golden horizon.

CHAPTER II

THE CONQUISTADORES



THE discovery of the New World, in 1492, marked an epoch in the history of mankind in general, and in no phase of it more particularly than the story of the precious metals. The motive of Columbus in seeking a westerly route to Cathay, Zipangu (Japan), and India was probably not altogether a passion for discovery, or a desire to enhance the prestige of Spain. It was to a certain extent a commercial venture as well as a voyage of discovery. Columbus was convinced that gold was to be obtained in the Indies, and he gave such a glowing account of the prospects of finding it, that he induced shrewd business men like Santangel, Quintanilla, and the Pinzons, to finance his expedition.

No sooner had the discoverer formally taken possession of Hispaniola, than he asked the natives for gold. They answered "Cubanacan," meaning Cuba. On November 14, 1492, Columbus was coasting Cuba, and wrote in his journal, "From the great heat which I suffer, the country must be rich in gold." Evidently he shared the quaint belief of his time that the tropics were richest in gold. Columbus was wrecked on the

Cuban coast, and having seen traces of the yellow metal, founded the colony of La Navidad. During his absence in Spain, his followers made a raid into the interior in search of gold, and were killed to a man. So began the long story of bloodshed which disfigures the story of the precious metals in America. Returning to Hispaniola after the fall of La Navidad, Columbus again turned his attention to the quest for gold. "Hearing of the mines of Cibao," wrote Helps,* "he sent to reconnoitre them: and the Indios, little foreseeing what was to come of it, gave gold to the Spanish messengers. Columbus accordingly resolved to found a colony at Cibao." But the gold-hunters were doomed to disappointment, for despite their most strenuous efforts, and their cruel treatment of the unfortunate natives, little gold was to be procured, for the simple reason that there were really no gold-mines—only a few poor "placers"—in Hispaniola.

Gold not being forthcoming, the whole native population was reduced to vassalage, and under the system of the *repartimiento* and afterwards the *encomienda*, the Indios became little more than slaves. Then when gold was discovered, the luckless natives were forced into the mines and condemned to a labour so exhausting and so unaccustomed that the mortality among them was frightfully heavy; so much so, that in the early years of the sixteenth century the Indios had become almost extinct, and natives of the Bahamas and even African negroes had to be imported to work the Cuban mines.

Columbus discovered the Central American mainland in 1502, and many exploring and marauding expeditions were sent there. Sixteen years later, Velasquez, Governor of Cuba, hearing of finds of gold on the mainland, fitted out an expedition to be commanded

* Vol. I. p. 132.

by that adventurous gold-seeker Hernando Cortes. The latter had procured gold in Cuba by means of an *encomienda* of Indios, "how many of whom died in extracting this gold for him God will have kept a better account than I," wrote Las Casas.* Velasquez, suspecting the *bona fides* of Cortes, revoked his appointment, but that wily adventurer had already weighed anchor and sailed for Mexico, where at Vera Cruz he openly avowed his hitherto tacit piracy and literally burned his boats.

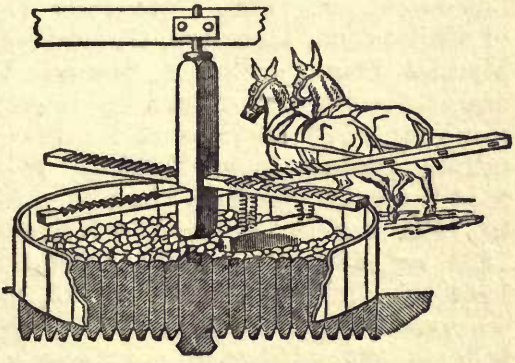
It is no part of my purpose to pursue in detail the story of the fall of the Aztecs under Montezuma, or the conquest of Mexico by this Spanish freebooter, Cortes. One authority (Del Mar) summarises it in the words: "The search for gold which was commenced with murder by fire and sword was continued with murder by the lash and the mine."

Some idea of the conditions which prevailed in the mines twenty years later may be gathered from the words of an eye-witness—one Fray Toribio Motolinia de Paredes. In a letter to Don Antonio Pimentel, Conde de Bonavente, dated February 24, 1541, the manuscript of which is still extant, the worthy Father Motolinia, who was "greatly honoured by his contemporaries and trusted by Cortes," gives an account of what he considers to have been the ten plagues of New Spain. Three of them are connected with the mines—viz. the gold-mines, the making of slaves in order to work them in the mines, and the transport service for the mines. In the description which he gives of the ninth plague, Father Motolinia dwells upon the mortality amongst the Indios engaged in the transport service of the mines. "They came from seventy leagues and upwards," he wrote, "bringing provisions and whatever was needful,

* "History of the Indies," lib. III. cap. 27, quoted by Helps, Vol. II. p. 249.

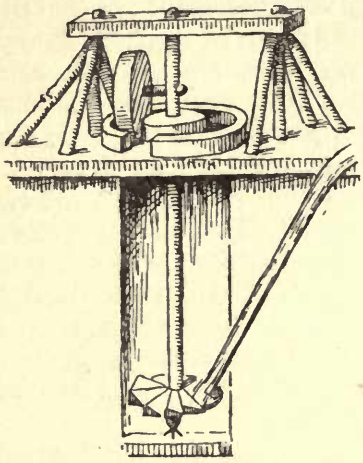
and when they had arrived, the Spanish mine-masters would detain them for several days to do some specific work, such as blasting a rock or completing a building. The provisions they had brought for themselves were soon exhausted, and then the poor wretches had to starve, for no one would give them food, and they had no money to buy it. The result of all this atrocity and mismanagement was that some died on their way to the mines; some at the mines; some on their way back; some (and these were most to be pitied) just after they had reached home." The worthy father goes on to assert that the number of deaths was so great that the corpses bred pestilence, and that in the mining district of Guaxacan (now Oaxaca), for half a league around it, and for a great part of the road to it, you could scarcely make a step except upon dead bodies or the bones of men.

In Mexico as elsewhere, the quest for gold went unremittingly on. Placers were discovered, and the gold was washed by means of a wooden dish or trough called a *batea*, which removed the earth until the diggings were exhausted—and still the demand was insatiable. Particles of the yellow metal were traced to their native quartz. Then came the problem which confronts the gold-miner to this day—how to extract the gold from the rock which contains it. It was soon realized that the



MEXICAN ARRASTRA.

first step, preliminary to any further process, was to grind or crush the ore to as fine a powder as possible. The Mexican *arrastra* or crusher was one of the earliest contrivances of its kind. The grinding of the ore was effected upon a stone bed or floor, over which heavy blocks of stone attached to arms, and rotating round a central spindle, were dragged by horses or mules.



MEXICAN MILL.

Mexico is exceptionally rich in all kinds of minerals, its mineral wealth being one of its main assets. Gold occurs chiefly on the Pacific slope and in greatest abundance in Sonora. It has been discovered from time to time in the States of Chihuahua, Durango, Guanajuato, Guerrero, Jalisco, Morelos, Oaxaca, Puebla, Sinaloa, Vera Cruz, Zacatecas, and to a limited extent in several other States. In the year 1906 there were no fewer than 1,572 gold-mining properties in Mexico. It has been computed that the total Mexican yield of gold from the year 1537 to 1821 amounted to £14,000,000 sterling, and from 1821 to 1880 to a value of £10,000,000. In the year 1905 the yield was valued at £3,221,000.

Among the early forays of the Spanish Conquistadores, that of Pizarro southwards was one of the most historic and remarkable. Pizarro's conquest of Peru can be compared only to Cortes' destruction of Aztec rule in Mexico, and was of equally fateful import to the inhabitants of vast regions of South America. In little

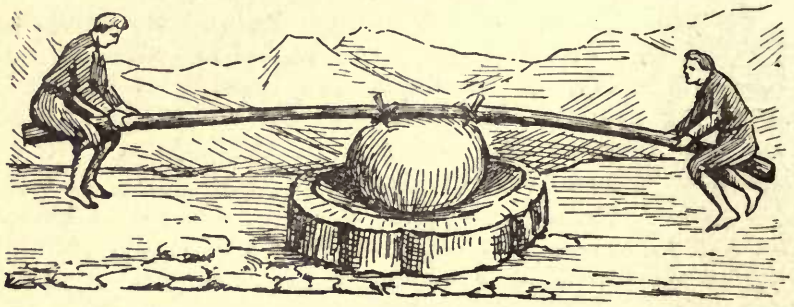
more than two years after leaving Spain on his final expedition, Pizarro and his handful of mail-clad adventurers had in 1532 captured the Inca city of Caxamalca and taken prisoner the great Inca, Atahualpa himself. One of Pizarro's most able lieutenants was Almagro, who, however, quarrelled with him and obtained a royal licence to explore and annex the vast territory including what is now known as Chile. Almagro started southwards in 1536, and crossed the Andes, penetrating to the Chilean valleys under Inca rule. He found no gold, however, and returned to Peru, only to meet with defeat and death.

Pizarro afterwards dispatched Pedro de Valdivia southwards. This energetic and ambitious adventurer founded the city of Santiago, and hearing of the discovery of gold at Malga-Malga, he soon had 1,200 men and 500 women working in the mines. These important mines of Malga-Malga, near Quillota, at one time yielded 30,000 pesos per annum. Others at Quillota and Limache gave 1,000 pesos of gold daily. There were other mines at Tucapel, at Arauco, and at Valdivia, where 8,000 Indians were employed. The historic mine of Madre de Dios has once more been opened up, and those of Oro del Inca are still to some extent productive.

Gold has been located at a great many places in Peru, notably in quartz veins at Salpo, Otuzco, and Arequipa on the Pacific slope, and at Cuzco and Sandia in the Amazon watershed. Alluvial diggings have been worked from time to time at such places as Pataz, Huanuco, Cuzco, Sandia and Carabaya (Puno). The last named are the more important and, it is believed, were the sources of much of the Incas' gold. The alluvial gold is found both in the beds of streams and in the soil of the pampas. The Aporoma deposit in Sandia is perhaps the best known. The long ditches with

stone-paved sluices, used by the Indians for gold-washing from a remote period, form a striking parallel with the methods in vogue in other lands. The Indians also constructed stone bars across the beds of streams to form riffles and hold the deposited grains of gold.

Reverting to Chile, we find that, as in most other gold-producing countries, the alluvial placers were worked first. Our illustration shows a *trapiche* or mill which was formerly used at the *lavaderos* or gold washings.



TRAPICHE AT LAVADEROS OR GOLD-WASHINGS.

Then with the exhaustion of the alluvial beds attention was turned to the auriferous quartz, which as we know required crushing before the gold could be separated by amalgamation. The later form of Chilean mill or *trapiche* for ore-crushing afforded an interesting variation on the Mexican *arrastra*. It was known among gold-miners as an edge-runner, and the grinding stones rolled round upon the stone floor while at the same time turning about a central upright.

Brazil, which was destined to become one of the greatest gold-producing countries of the world, was

discovered by Vincente Yanez Pinzon, a Spaniard, in the year 1500. The presence of gold was suspected as early as 1543, as the Indians made their fish-hooks of it. It was not until 1577, however, that gold placers were first located in Brazil.* The first white man to find gold was one Antonio Rodrigo, who discovered it on the banks of the Riveao, a tributary of a larger river since known as the Rio des Mortes, near the present town of St. John del Rey. Rodrigo died shortly afterwards, and bequeathed his find to his son. The Paulistas or people of San Paulo, Rodrigo's native place, also came on the scene. The lust for gold once more led to bloodshed, and the Paulistas killed one another in such numbers on the banks of the river that it has ever since been known as the Rio des Mortes or "river of death." The banks of this stream soon became labyrinths of rude surface workings, and the gold obtained was long considered the finest in Brazil. North of the town of St. John del Rey is that of Villa Rica, originally called Ouro Preto. On large quantities of gold being discovered they called the new mining town that had sprung up Villa Rica (Rich Town).

For a long time the gold was only recovered from the clay through which the rains from the mountain sides had filtered, leaving behind the particles of precious metal. The early mines were thus simple pits called *catas*. These were worked downward until the gravel below was reached. The gravel, or *cascalhâo* as the natives called it, was a sandstone conglomerate. It was ferruginous, the presence of iron being clearly marked. The gold lay, according to Mr. Mawe † and Dr. von Spix, in the stratum of rounded pebbles and gravel incumbent on the solid rock. The *cas-*

* Baron von Humboldt's "New Spain," III. p. 401.
† "Travels in Brazil."

calhâo or gold-bearing gravel, cemented together with the oxides of iron, was taken to the river to be washed; or, where possible, water was conveyed to the gravel, which was washed *in situ.* These works were called

PRIMITIVE MINING.

lavras, and anticipated modern methods of hydraulic mining. There was in Brazil, however, a dry and a rainy season, and in the dry season there was often a shortage of water.

The most primitive methods at first prevailed at

the alluvial diggings or river-side gold-washings, gourds or wooden bowls being used for the purpose. Later, when water could be obtained at a sufficiently high level, the ground was cut in steps from twenty to thirty feet long, two or three feet broad, and a foot high. Upon each step stood six or eight slaves, who, as the water flowed gently downwards, kept the earth agitated until it was reduced to the consistency of liquid mud, and flowed away. At the bottom of such a series of steps was cut a trench into which the precipitation flowed, and where after five days' washing it was considered fairly well cleaned up. The auriferous deposit was then removed by hand to the nearest stream and there subjected to the bowl process of separation or washing.

The gold-bearing drift was followed until it was traced ultimately to the outcropping reefs of quartz. For some distance below the surface the rock was decomposed and was easily worked by open trenches cut into the hillside. But when the solid rock was reached, the skill and enterprise of the native miners, who had so far been remarkably successful, was baffled and set at naught.

The mining district of Minas Geraes is situated in the mountainous country of Brazil north of Rio Janeiro. It is about one hundred miles in length, having Villa Rica and St. John del Rey and the adjacent mines to the south, and the mines of Gongo Soco some eighty miles to the north. The first gold was found at Gongo Soco by a solitary Portuguese, named Manuel Camara, who worked the placers with his own hands and amassed a fortune. But as usual the news spread and many treasure-seekers flocked to the vicinity.

These Brazilian gold-fields lay in mountainous country, and at that time were very difficult of access.

Food and supplies had to be brought great distances upon the shoulders of slaves. From Ouro Preto to Rio de Janeiro, for example, was 200 miles, or fifteen days' journey, and from Matto Grosso near the Bolivian frontier, to Para, the distance as the crow flies is 1000 miles, or, by the river route, 2500 miles.

At first the only food to be obtained in the mountains was "a few white deer and mangabas—a species of wild fruit." * The price of corn at the mines was more than a pound of gold (£50) per bushel. In at least one instance the same price was paid for a pound of salt.

Between 1694 and 1718 rich placers were discovered at Goyaz and Matto Grosso. These drifts were at first extraordinarily productive, the slaves employed by the gold-miners frequently obtaining for their masters three and even four ounces of gold in a day. This unusual richness did not last beyond the first year, although until after the middle of the eighteenth century the placers were moderately productive.

During the first rush to Goyaz and Matto Grosso, a herd of cattle which some adventurer had driven all the way to the mining camps realised an ounce and a half of gold (say £6) per pound gross weight—that is flesh and bone together. It required practically all the gold which the miners could obtain to keep them in food, and sometimes they found even this impossible, for numbers of them died of leprosy and starvation.† We are told, too, that many of these early gold-miners were the worst of characters—outlaws and renegades. As the settlements grew, the tone gradually improved. But the Brazilian mining communities were notorious —not only for their treatment of slaves, whom they made captives and then worked to death, but also for their proneness to violence, their quickness to use

* Del Mar, "History of the Precious Metals," ch. xvi. p. 118.

† Macgregor, IV. p. 210.

the knife on all occasions, their passion for gambling, and general licentiousness.

At Gongo Soco, one of Camara's successors was the first to realize that he was working only the refuse of a great mass of virgin gold. He set out to prospect in the mountains beyond and, sure enough, found a lode or bed of rich gold-bearing ore forty feet wide. Shafts were sunk and levels cut, and the lode gave such profitable results that eventually, in 1825, it led to the formation of the Imperial Brazilian Mining Association.

Gradually the tidings of the richness of the Brazilian gold-fields penetrated to Europe. Many Argonauts, English and German miners for the most part, crossed the Atlantic. Concessions were obtained from the Brazilian Government, surveys were made, and proper mining operations were begun. Shafts were sunk and huge stamping machines, made of wood, were set up for the purpose of crushing the quartz. It was to work a concession on the Morro Velho estate that the English concern known as the St. John del Rey Company was formed in 1830. Adjacent mines have been worked since 1725.

It would be difficult to exaggerate the richness of the Brazilian gold-fields or the commercial importance of their immense yield in those early days when adventurers were scouring the earth and the seas in search of gold. It could truly be said that the might of Portugal at the zenith of her power was based on Brazilian gold. As for the actual output of the Brazilian mines, it is, contrary to the usual experience, possible to give the estimated product more accurately for the earlier than for later periods. The Abbé Raynal, a recognised authority, has written * : " It

* " History of the East and West Indies," Third Ed., London, 1779, Vol. II. p. 549.

is demonstrable, *from the registers of the fleets*, that, in the space of sixty years, that is from the discovery of the mines to the year 1756, 2,400,000,000 livres (about £96,000,000) worth of gold have been brought away from Brazil." This was a gigantic total for those days of primitive and inefficient methods and plant.

In order to avoid the heavy royalties, fixed for the most part at 20 per cent., and the *haberia* or convoy charge imposed to cover the cost of the men-of-war which convoyed the fleets of merchantmen in those troubled times—a good deal of smuggling or unofficial transportation of gold took place. Taking these factors into account, Baron von Humboldt in his "New Spain" estimated the total gold production of Brazil from 1680 to 1803 at £171,100,000. During those stirring years the stories of the gold-laden galleons of Spain and Portugal were no mere figments of the imagination.

Then came a reaction from which the Brazilian mines suffered in common with all others in Spanish and Portuguese America. One of the most striking and far-reaching results of the French Revolution and the invasion of Spain by Napoleon's army was the overthrow of Spanish rule in the New World—the revolt which began in 1810, and, sweeping through Mexico, eventually resulted in liberating, not only every State of Spanish America, but also every slave in every mine—thus ending for ever the horrors of subterranean slavery and initiating the era of free mining.

But on the other hand, in so far as the practical working of the mines was concerned, the Spanish-American revolution had the most disastrous effects. In the mines of Mexico and Brazil the workings were neglected, and frequently caved in and became full of

debris or water. The machinery and plant generally rusted, and buildings collapsed into ruins. Not only labour but capital was withdrawn from the mining industry in the districts affected. The production of gold consequently fell off in the case of Mexico by more than one-half, and also in the whole of Spanish America —comparing the two periods 1796–1810 and 1811–1825. It was many years after the close of the Spanish-American revolution before the mines had regained their old level of production.

The effect of this decline in the production of the precious metals in Spanish America on commerce and finance was most profound. The mines of the New World had been for a long period by far the most important sources of supply of gold and silver to European nations. An economic upheaval and a calamitous fall in prices were apparently inevitable, and it was with the object of averting such a dislocation of commerce that the banking system, as we know it to-day, first took shape. Notwithstanding such precautionary measures, financial crises were frequent during this period when the scarcity of the precious metals began to be felt in banking and commerce generally.

Gold-mining as an industry has lost much of its importance in Brazil, as, despite the introduction of modern methods and machinery, and the occasional discovery of new fields, the output, on the whole, continues to decline. Only the abandoned workings remain to bear silent witness to the literally golden days of yester-year.

In the state of Minas Geraes ("general mines"), usually known as Minas, there were in 1908 five deep mines worked by English companies and one by a French concern. During the same year (1908) a rich gold-field was discovered in the northern part of Minas, five miles from Montes Claros, in the valley of the

Verde Grande River, and it attracted a large number of gold-seekers.

The shortage of gold due to the stoppage of the Spanish-American mines, and the ever-increasing demands for the yellow metal for currency and other purposes, turned attention to the Russian mines, which hitherto had been productive only on a small scale.

The oldest gold-mine in Russia is that of Voetsk, near Olonetz, between Lake Onega and the White Sea. It was worked during the early part of the eighteenth century, but from 1744 to 1776 only yielded some 57 lb. of gold and some copper. As this output was not sufficient to enable the mine to be worked as a paying proposition, it was closed down, and has since been worked only intermittently.

The gold deposits of Ekaterinburg were discovered in 1723, but were not properly opened up until twenty years later.

The famous mines of Berezovsk, east of the Urals, owe their origin to the discovery of gold in 1752. Originally the gold was procured from alluvial washings, but afterwards it was obtained from the shallow shafts and adits driven into the quartz veins in the adjacent rocks. Towards the close of the eighteenth century the Berezovsk mines yielded from 600 to 800 lb. (Troy) of gold annually.

The gold washings of the Ural proper were taken over by the Russian Government in 1814, those of Western Siberia in 1829, and those of Eastern Siberia in 1839.

Many of the Siberian mines and diggings, like those at Kara—alone in an age of civilization and free mining—were worked by convict labour. Gold dust is found in almost all the mountainous regions fringing the great plateau, and notably in the Altai and the Olekma. It is also found on the upper Vitim and on the Zeyanear

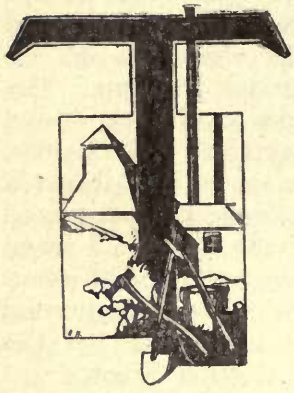
Nerchinsk. In Eastern Siberia gold is obtained almost exclusively from gravel washings, quartz-mining being carried on only near Vladivostok and in Transbaikalia. In Western Siberia, on the other hand, quartz-mining is steadily displacing the gravel washings in importance. The yellow metal has been located, too, in the Bureya range and the Amgun region.

The yield of the Russian gold-mines was, in 1829, according to Baron von Humboldt, valued at £720,000. In 1841 this output was doubled, and again increased to £2,600,000 two years later. But even this increased supply was inadequate to meet the demands of the growing population and commerce of Europe. The mines of gold in the Russian Empire again responded to the insistent demand by producing £3,800,000 worth.

With the discovery of the yellow metal in California the Russian output reverted to the normal and remained practically stationary for many years. It had been taxed to its uttermost, and its resources were insufficient to meet the expanding requirements of the commercial world, which turned with interest and relief to the tidings of the new Eldorado in the Golden West.

CHAPTER III

THE GREAT GOLD DIGGINGS



THERE are no more striking examples of the accidental nature of the discovery of supplies of the precious metals than the locating of the gold placers. The presence of gold in California had been long suspected, but the actual finding of it in a district which virtually teemed with the yellow metal was the outcome of as amazing a chapter of accidents as ever happened outside the covers of a novel.

The Spaniards, primarily intent on securing supplies of gold and silver, discovered and partly explored California in the sixteenth century. Cortes visited it from Mexico in 1537 and returned with a small quantity of gold. Spain retained possession of California undisturbed for three centuries, established missions there, and converted and pacified the Indians. But they found little gold, and the few prospectors and gold-seekers returned to Mexico and Spain disappointed. Drake was said by Hakluyt to have seen traces of gold in Alta California in 1577–1579. The presence of the yellow metal was mentioned, in a work published in Spain in 1690, by Loyola Cavello, a priest at the mission of San José,

and again in the historico-geographical dictionary of Antonio de Alcedo (1786–1789). It is difficult to understand why these repeated discoveries were not followed up. It was no doubt due in part to the inaccessibility of California, and in part to the waning power and prestige of Spain and the slackening enterprise of her sons. Whatever the explanation, the fact remains that no systematic prospecting for gold was undertaken, despite repeated finds and traces, for nigh three hundred years.

Coming to more modern times, the first well-authenticated discovery of gold in the nineteenth century was at Los Angeles in 1842. Professor J. D. Dana, in his report on California, commented on the fact that the geological structure of the country favoured the idea of the presence of gold. By this time many Americans had found their way into California, and after the presidential election of 1844 in the United States, the war with Mexico broke out. Mexico was of course defeated, and by the Treaty of Guadelupe Hidalgo, signed in February 1848, California was ceded to the United States as an indemnity for the costs of the war.

It was a remarkable coincidence that the historic discovery which was to make California the El Dorado of the early nineteenth century synchronized with the hoisting of the stars and stripes. The actual finding of the precious metal was made in the most amazingly casual fashion. It all came about through a European settler wishing, after nine years' residence, to improve his holding.

Johann Sutter was an unexpectedly cosmopolitan figure to find in these western wilds. German by birth, Swiss by descent, he was French by training, having been a captain in the bodyguard of Charles X. He had, in the year 1839, settled near the American River, not

far from the site of the present town of Coloma. Nine years later, Sutter, then a wealthy settler, was having a mill built and a channel excavated for the water-supply, under the superintendence of James W. Marshall, his overseer. On January 24, 1848, Marshall was trying to enlarge the tail race by sending down little freshets of water, when he noticed little glittering particles in the channel. He tested them, and found them to be gold. Sutter was told, and the mill workmen came to know. Henceforward any attempt at secrecy was in vain. Other finds of gold were quickly made in the neighbourhood, and the news of the original epoch-making discovery spread rapidly. It was soon found that the banks of the Sacramento River, and the bed of nearly every mountain stream in the vicinity, simply teemed with gold.

The news spread like wildfire. The infant port of San Francisco was deserted. Merchants and clerks, lawyers, doctors, and even State officials, joined in the rush to the gold-fields. Soldiers and policemen left their posts, and no sooner did a ship drop anchor in the bay than the crews took French leave and hurried ashore to join in the race for gold.

As the tidings spread further afield, men came from every part of America, and, after a time, from Europe and even from Asia. First came immigrants from Oregon, Mexicans from Sonora, Kanakas, Peruvians, Chilians, and Chinamen. But the new gold-field was in those days extremely inaccessible. On the land side it was shut in by a double chain of lofty mountains, while these were separated from the Eastern States by a couple of thousand miles of prairie and waterless desert, only partially explored. To reach California by water from the Atlantic meant a long and stormy voyage round Cape Horn, or a couple of shorter ones sandwiching a land journey across the unhealthy

Isthmus of Panama. But the golden magnet was strong enough to overcome all obstacles.

The overland migration of 1849 was a marvellous exodus—one almost without parallel in modern times. Bayard Taylor records that, between August and December of that year, no fewer than 30,000 souls accomplished the journey of over 2,000 miles, through a savage and only partially explored wilderness, crossing *en route* two mountain chains equal to the Alps in altitude, and broad tracts of burning salt and alkali desert where the desolation was relieved only by a few cacti, stunted shrubs, and brackish springs.

Nor were natural obstacles the only ones to be overcome. The nomadic and warlike tribes of Red Indians—the Pawnees and the Sioux—at first actively resented this invasion of their hunting-grounds, though latterly they were daunted by the magnitude of this unending stream of white men, ever moving westwards. The cholera swept over these modern seekers of the Promised Land, and laid a heavy toll upon their numbers, but still the living stream swept on up the long slope of the Rocky Mountains, past the Great Salt Lake, and on until the welcome western slope of the Sierra Nevada was reached, when the great interior Wilderness of the Plains resumed its ancient silence and solitude until the following spring.

Then, almost a year after the first discovery of gold in California, came the flood of emigrants from Europe—the majority of them from the British Isles. They came in their tens of thousands, these modern Argonauts, crowded and half starved, in leaky ships for argosies. They landed either at New York or some other Eastern port, thence to begin that terrible overland journey, and perchance leave their whitening bones to mark the trail, or sailed right onward on that equally arduous and perilous voyage round the Horn. So,

despite the distance and inaccessibility of the Californian gold-fields from the older and greater centres of civilization, the golden lure was strong enough to attract a large miscellaneous and polyglot population to the Pacific slope.

The output of gold from the new diggings was phenomenal—colossal! Nothing like it had ever been known before in the modern world. Those fortunate pioneers who first secured possession of the rich bars on the American, Yuba, Feather, Stanislaus, and other smaller streams in the heart of the gold region, sometimes made as much as $5,000 (£1,000) in a single day. During 1848 from five to seven hundred dollars (£100 to £140) daily were not unusual results. Gold dust became the generally accepted currency, but it rapidly depreciated in value from seventeen to four dollars an ounce. The cost of living was of course proportionately high.

During the first rush to the diggings, the *Californian*, a San Francisco newspaper, had to suspend publication for want of printers and readers alike. When publication was resumed, the editors stated that their publisher, "when on a tour alone to the mining district, collected with the aid of a shovel, pick, and tin pan about twenty inches in diameter, from 44 to 128 dollars a day, averaging about 100 dollars (£20)." *

The Californian boom marked the opening of a new chapter in the history of mining—that of liberty as opposed to slavery. The "forty-niners" were the first free miners; but liberty at times degenerated into licence. Life at the diggings had to be lived under the most primitive conditions. Law and order as known in older communities were practically non-existent. Every man had, in the last resort, to depend

* "Annals of San Francisco," by Frank Soulé, John H. Gihon, and James Nisbet. New York, 1855.

upon the strength of his own right arm, or his dexterity in drawing a pistol or bowie-knife. Mêlées were frequent among the miners, particularly in the many drinking and gambling saloons which rapidly sprang up. "Squatting" or jumping claims in the absence of the owners was not uncommon. Possession was the only law recognised except the summary jurisdiction of the Vigilance Committees. It was a significant sign of the times that when a dead body was found floating in a river it was regarded as proof of foul play, as a gold-digger who was accidentally drowned ought, people said, to carry enough gold to keep his body under water.

There was, however, a brighter side to life at the diggings. Freed from the conventions of civilization, men "bearded like the pard" lived and dressed as they pleased, generally in an unstudied and picturesque fashion. They spoke a new and quaint lingo "full of strange oaths," the jargon of the craft, and relieved by a shrewd wit and a grim humour preserved for us by American writers like Bret Harte.

Early operations on the Californian placers were at first confined to surface diggings, but even this scratching of the surface produced a veritable golden harvest. Within a couple of years California was producing gold to the value of £10,000,000 sterling per annum.

Gold-washing with the pan—a circular dish of tin or iron from 13 to 20 inches in diameter, with sloping sides—was the earliest method and the one most in vogue among individual miners. The gold-seeker held the pan, half full of "pay-dirt," slightly below the surface of a current of water. Shaking or stirring the contents and rejecting the larger stones, the pan was gradually raised as the earth was washed away. Ultimately the motion and flow of water carried off the whole mass, save a little black sand mixed with

the golden particles. After drying, the sand was easily blown off and only the gold remained.

Before very long the primitive pan was improved upon by the invention and construction of a contrivance known as a cradle or a rocker. It was a crude machine, often made of a dug-out log or a trough mounted on rockers. It was from 4 to 8 feet long, was sloping, open at the foot, and had at its head a coarse grating or sieve. The bottom was rounded, with small cleats nailed across. Three men were needed, beside the actual diggers, to work this machine. One carried the auriferous gravel to the cradle and emptied it on the grating; another gave the machine a violent rocking motion, while a third dashed water over the moving gravel. The grating kept out the stones, the current of water washed off the earthy matter, and the gravel gradually descended to the lower end of the cradle, leaving the golden sands lodged in the upper cleats. This was drawn off, dried, and separated by blowing as in the pan. The cradle, though fitted latterly with a perforated sheet-iron bottom and a canvas screen, is unchanged in principle, and has remained in use in undeveloped alluvial diggings ever since.

The Californian mining settlements of 1848–1849 were located, for the most part, along the shallow placers of the American Cosumnes, and Moquelumne Rivers. By 1850 the large camps had spread northward as far as the North Fork of the Feather, and into Mariposa county on the south. The following year saw much activity as far north as Shasta.

By that time the rocker had given place to the larger "Long Tom," which was more effective on account of the riddle plate over the riffle-box, and still more because of the extended sloping sluice, and the greater quantities of water used in washing. Mercury

and amalgamated copper plates began to be used in conjunction with the Long Tom at the alluvial diggings.

The evolution of mining appliances, dictated by local requirements, was in California extremely rapid. About the year 1851 the broad sluice was devised, and soon revolutionised the whole rationale of placer mining. In its typical form the sluice was a trough, generally about 12 feet long, from 16 to 20 inches wide, and a foot deep, and tapering slightly so that it could be joined up in a series, often hundreds of feet in length. A stream of water with a good " head " or flow was caused to pass through the sluice. Across the sluice-bottom were fastened riffles or cleats of wood which caught the particles of gold, and were made easily removable for the " clean-up." The paying gravels were simply shovelled from the claim into the sluice, and so were carried down to the " tailings " dump, depositing their gold *en route*. This process was continued for several days, and then came the " clean-up " or recovery of the gold.

River-bed mining, undertaken on a small scale in the early years of the Californian rush, developed later into a series of gigantic and boldly conceived enterprises. This " fluming," as it was called, was one of the most dramatic of the miners' many contests with nature. In this type of mining the first step was to divert the course of a river or stream by means of a dam and a canal or flume. The bed of the river would thus be left bare, and the gold-bearing sands and gravels could be worked without hindrance. The flume carried along the whole body of the stream, which was utilised to turn water-wheels and so pump from the river bed any water which might collect there. The preliminary expenditure involved the employment of considerable capital, and the operations were long and arduous. A little army of labourers

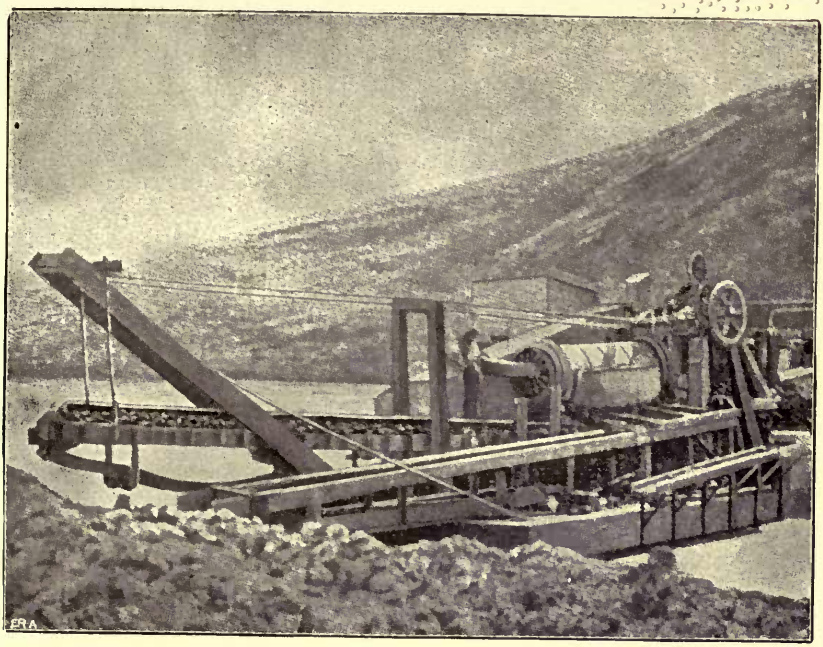
had to toil all through the summer, when the streams were low, for the hope of a few weeks of golden harvest before the autumn rains came. Frequently, as in the year 1850, early rains swept everything away, and the season's labour was lost.

Not only were the courses of rivers diverted in the feverish search for gold, but immense supplies of water had to be brought to work the deep placers or great gold-bearing gravel beds, which lay far away from any existing watercourse. Tunnelling and hydraulic operations were carried on on a large scale. Water was brought from the mountains a dozen, thirty, or more miles away in channels or " ditches " cut in the rock, and carried in troughs over valleys and ravines, or stored in reservoirs near the gravel beds. But hydraulic mining is so important and distinctive a phase of gold-mining that it may well be reserved for treatment in a separate chapter.

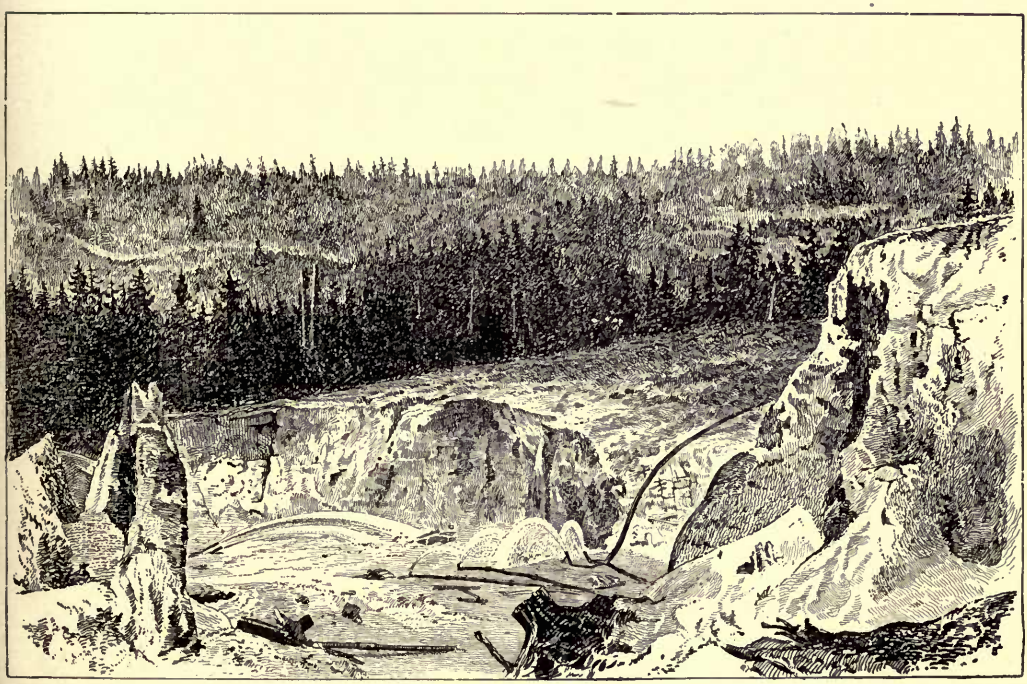
The Californian boom was, however, comparatively short-lived. After 1853 the total output of gold began to decline. The shallow placers in gulches or ravines and river-beds became exhausted, and the deep placers or gravel beds had not begun to be either workable or remunerative with the appliances then in use.

Further exploration showed that the great gold region of California forms a belt along the western slopes of the Sierra Nevada and extends westwards to the Sacramento River. The gold veins or auriferous quartz are found in rock in some places at as high a level as the summit of the range (as in the Sierra Buttes), while the alluvial deposits are comprised in a zone from 15 to 30 miles in breadth across the foothills of the Sierras.

The whole surface of the country has undergone a complete and striking transformation since these great



THE DREDGE "GOLD BANK."



HYDRAULIC MINING ON THE GEORGETOWN DIVIDE.

gold-bearing quartz gravel beds were deposited. The reconstruction of the primeval topography of golden California reads like a geological romance. The greatest of the gravel beds, the "Big Blue Lead," which is a mile wide, 400 feet deep, and can be traced for 50 miles, was formerly the bed of one of the prehistoric rivers of the Pliocene system which in the remote Tertiary age ran north and south, athwart the courses of present streams. In course of ages the deep and water-worn channel in the rock, now called the "rim-rock," became filled with quartz boulders—the debris of mountains that have almost completely disappeared. Volcanic action possibly intervened, but in any case the process of weathering or denudation has gone on all round, so that this ancient river bed is now a thousand feet above the level of the Bear River, and 1,500 feet above the Sacramento. Such in brief is the story of the "deep placers" of California, graven on the world-old rock by the fingers of Time and the elements.

After the deep placers or gravel beds had reached their maximum productivity, which was secured, as we shall see, by "hydraulicking" or hydraulic mining, there came another phase of the quest for gold in California. The miners set themselves to search for the parent rock from which all this quartz gravel had been disintegrated. Their search for a range of quartz mountains was however in vain. They were forced to the conclusion that such mountains no longer existed; they had crumbled away in the course of ages. All that was left of them were the immense beds of gravel.

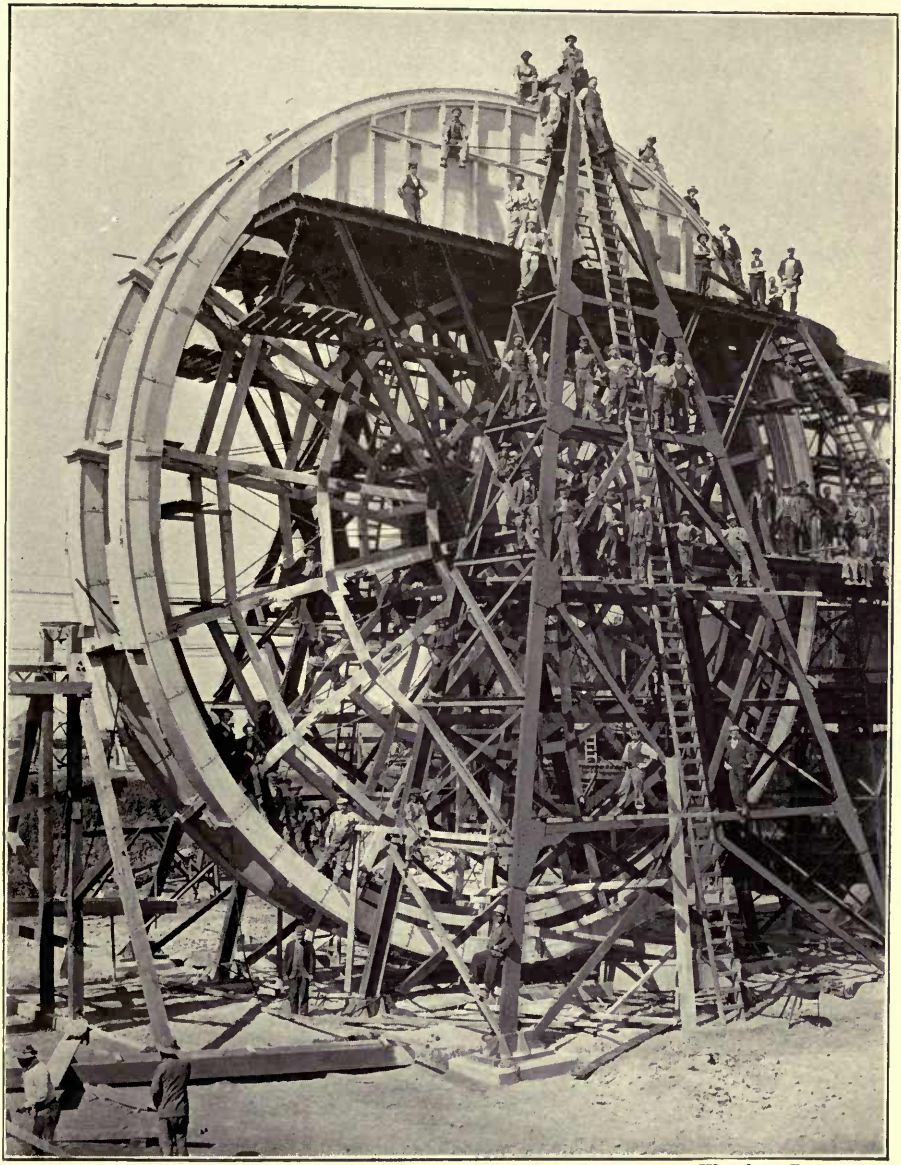
Beneath this alluvial gold belt there runs a great auriferous quartz vein, a Veta Madre or "Mother Lode," varying from 6 to 30 feet in width, and descending to a great depth in the native rock. This Mother Lode

of California can be traced for a distance of 60 miles, and crops out in many places like an immense wall, forming a striking and picturesque feature of the landscape.

As the "placer diggings" of California became exhausted the gold-miners turned their attention to the quartz. It was soon found that the appliances then in use in other parts of the world did not suit local conditions and were not adapted for the treatment of gold-bearing quartz on a large scale. Prior to the year 1861 quartz-mining in California was in a merely experimental stage—the placer miners jeeringly calling the shafts "coyote holes"—but about that time the quartz lodes began to be efficiently and systematically mined.

The quartz-mining was at first carried on on what is known as the "free-milling" system—that is simply taking the ore from the mine, pulverizing or crushing it by means of a battery of "stamps" or crushers, working like pestles in a mortar, and extracting the gold by taking advantage of its chemical affinity for the quicksilver coating of numerous copper plates. But only a small percentage of the gold in the ore was secured by this process, the quantity of the yellow metal which can be separated by the agency of quicksilver being a comparatively small proportion of the assay value of the ore. The remainder of the gold was carried away in the outflow of water from the battery, and got lost in the "tailings" or waste. This often turned the scale and made the mine a commercial failure. Experience taught the necessity of adopting new and more efficient methods, and quartz-mining gradually developed into an industry worked on scientific lines, so that ores once considered "unpayable" or refractory can latterly be dealt with profitably.

The Eureka, in 1866, was the first quartz-mine to



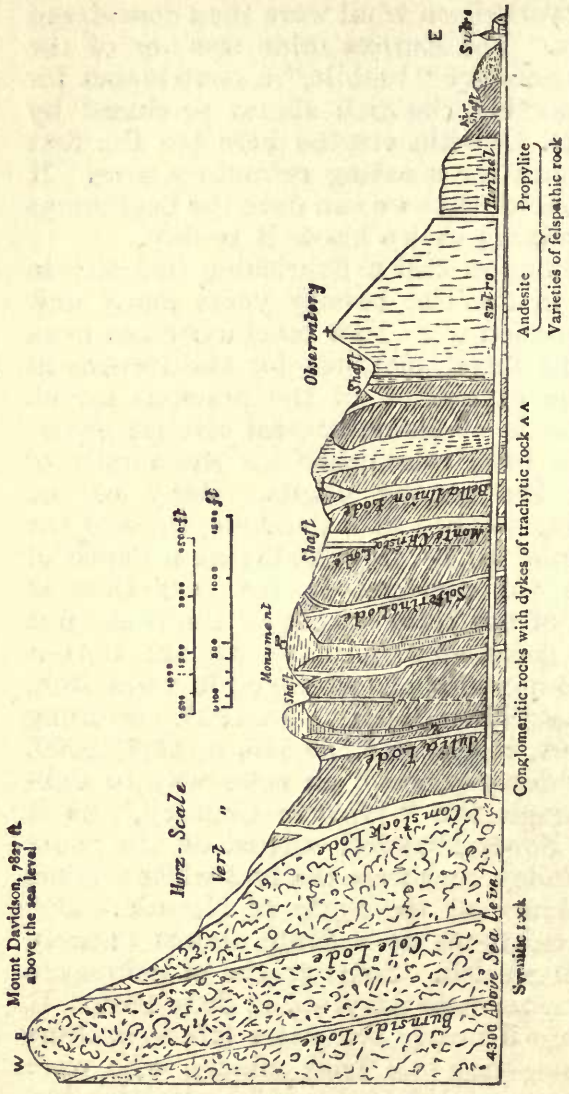
Wernher, Beit & Co.

TAILINGS WHEEL, FERREIRA DEEP MINE.

be opened up and worked on what were then considered scientific principles. The Eureka mine was one of the earliest to use the concave "buddle," a contrivance for concentrating or sorting the rich slimes produced by the stamps. A Mr. Deetkin erected here too the first reverberatory furnace for roasting refractory ores. It is in fact from this point that we can date the beginnings of practical gold-mining as we know it to-day.

Quartz gold-mining is still a flourishing industry in California. Even in the last twenty years many new mines have been opened up. New machinery has been introduced, with the latest methods for the treatment of the ore and the extraction of the precious metal. Where water power is available central electric generating stations have been established for the supply of electric power to the mining plants. Many of the mines are now being worked at a great depth, and the veins are often found to be as valuable at a depth of 3,000 feet as near the surface. In the year 1908 at least three-fourths of the total output of the State was derived from the quartz-mines. The annual output from the year 1875 onwards has averaged in value from fifteen to seventeen million dollars. In 1905, according to the Mines Report, it was $18,898,545, or £3,839,000.

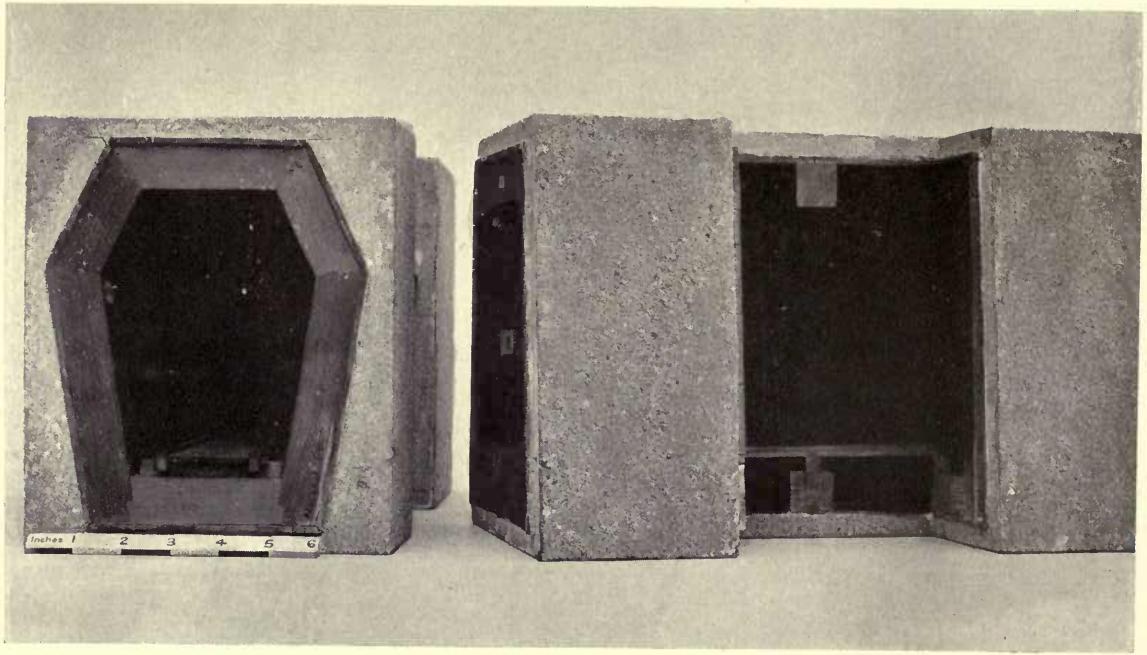
Many of the "forty-niners" on their way to California passed through the "Washoe Country," as it was then called. Several traders settled on the route along the Carson Valley, and were the first white settlers in what we now know as the State of Nevada. But Nevada owes its existence as a State almost entirely to its own mineral wealth. Some traces of gold were found in Gold Canyon, near Dayton, in July 1849. It was not however until nearly ten years later—in June 1859, to be precise—that two Irish miners, who were fated to die, one insane and the other in hospital, located that marvellously rich deposit of the precious metals, the



SECTION ACROSS COMSTOCK LODE AND STRATA.

Comstock Lode, which has since become world-famous.

The unique nature of the lode was not realized all at once. At first it was worked for gold only, and from 1862 to 1868 the average annual gold production was about eleven million dollars. In the meantime Virginia City, a prosperous mining town, had sprung up on the bare mountain side, where otherwise no such community would have existed. In those early days the miners, in their ignorance, threw away the "black stuff," which afterwards proved to be silver ore with an assay value four times as great as that of



MODELS OF LEVEL TIMBERING, COMSTOCK MINE.

the ores of gold. The opening up of the Great Bonanza Mine by John W. Mackay and his partners Flood, Fair, and O'Brien, synchronized with the second period of maximum productivity (1873–1878) of the Comstock Lode. During this period the annual yield averaged $26,000,000. For the three years 1875–1877 the production of gold and silver in Nevada was more than that of all the other States of the Union combined. After that the output of the Comstock mines declined on account of the partial exhaustion of the ore supply, the increased cost of mining at great depths, and depreciation in the price of silver. From 1893 onwards the output of gold predominated, and since 1899, with the introduction of improved machinery and the treatment of old tailings by the cyanide process, the production has again begun to increase. Up to the end of 1902 the Comstock mines had produced $148,145,385 worth of gold.

A unique feature of the Comstock mines is the Sutro Tunnel, built between 1869 and 1879, and named after its engineer Adolph Sutro. Beginning on a distant hillside far below the level of the mouths of the mines, it strikes the shafts after traversing a distance of over four miles. It ventilates and drains the mines, and obviates much pumping and hoisting.

Another Nevadan mining region of some importance was the Eureka district, where ore was discovered in 1864. The mines did not become remunerative for some five years, but before 1882 over twelve million pounds worth of the precious metals had been extracted.

After the working out of the Comstock deposits, there was a slump in mining in Nevada which lasted for many years. In May 1900 very rich deposits of gold and silver were located in Nye county, and this proved to be the herald of a new lease of prosperity. Within two years precious metals to the value of seven million

dollars had been collected, and in 1903 the adjacent mining town of Tonopah had 4,000 inhabitants. Other finds were located in the Goldfield District of Esmeralda county in 1902, and in Bullfrog District in Nye county in 1904. As an instance of the combination of mushroom growth and American " hustle " in these western mining towns, Bullfrog boasted that within ninety days after its birth, although one hundred miles from a railway, it had an electric lighting installation, an ice plant, and an hotel. Manhattan, where gold was located in 1905, was by March 1906 a village a mile in length and containing a population of 3,000.

Colorado, once the greatest silver-producing State in the Union, now takes a high place in the production of gold. The prosperity of the gold-mining industry is mainly due to the discovery of the rich deposits of the rare telluride of gold at Cripple Creek in Teller county. This district, which prior to 1891 was almost unknown and practically inaccessible, is now approached by three railway lines and is a centre of the greatest industrial activity.

There have been three distinct phases in the exploitation of the precious metals in Colorado. Previous to 1879 gold was the principal product. In that year silver ore was located at Leadville, and until 1894 the white metal took premier place. Then, even at Leadville, gold once more took the lead. In 1897 the production of gold in Colorado first exceeded that of California. Eight years later the yield was valued at £5,139,800.

I must not linger too long among the picturesque prospectors and diggings of the Rockies or the busy mines of the Far West, but must needs hark back and take up the thread of the story of the gold-mines with that other great event of the mid-nineteenth century—the rush to the Australian gold-fields.

THE GREAT GOLD DIGGINGS

The Australian Gold Rush

The short history of the Island Continent has been, with one exception, a comparatively uneventful one. Acquired peacefully by right of discovery, its remoteness placed it outside the theatre of the world's action. That very remoteness, too, doubtless led to its selection as a place of exile for the thousands of convicts who were transported thither under the rigorous penal laws of other days. The more humane regime which led to the abolition of transportation saw the dawn of happier days for Australia, and its development as a pastoral and agricultural country proceeded on more normal lines. In the year 1850 self-government was granted to the infant colonies, but that event was overshadowed by the sensational discovery of gold in quantities which were calculated to outrival even the rich yellow placers of Golden California.

Even prior to the Californian boom, it had been known that the precious metal was to be found in Australia. The aborigines knew of it, and often made their arrow-heads of gold. A despatch of the Lieutenant-Governor of the Colony to the Secretary of State, dated September 2, 1840, enclosed a report from Count Strzelecki stating that he had discovered auriferous pyrites in the Vale of Clwydd in 1839.* The Count afterwards stated that he was urged to keep the discovery secret for fear of ruining the discipline of the 45,000 convicts. In 1841 the Rev. W. B. Clark also found gold, and in 1848 a survey was undertaken by the Government at the suggestion of Sir R. J. Murchison. It is generally admitted, however, that the first great discoveries of 1851 were not due to any of these observa-

* "Thirty Years in New South Wales and Victoria," quoted in Phillips's "Mining."

tions, but to the chance prospecting of a Californian miner named Hargraves, and some others.

The year 1851 was indeed a golden year in Australian annals. The first discovery of gold was made on the banks of the Macquarie River, New South Wales, in February, and by June 1 there were over 1,000 men at the diggings. On June 10 gold was found on a tributary of the River Loddon, on July 20 at Mount Alexander, and in August at Mount Buninyong and Clunes diggings—all in Victoria. Finally, on September 8, came the locating of gold by Hargraves at the junction of Lewis Ponds and the Summerhill Creek near Bathurst in the Ballarat district. It would seem as if the momentousness of the discovery was instantaneously appreciated. Within a month upwards of 7,000 miners were at work on the Ophir Diggings. By the end of this wonderful year, 1851, the number of diggers on the Australian placers was from 15,000 to 17,000, and nearly £1,000,000 worth of gold had been extracted. The growth of the gold-mining industry in the following year was even more phenomenal. The number of miners increased to something like 150,000, including about 9,000 convicts on ticket of leave.

The early history of the rush to the Californian gold-fields repeated itself on the other side of the Pacific. The whole social and industrial organism of the colonies, and particularly of Victoria and New South Wales, was dislocated. The colonists were the first to leave their homes and ordinary avocations for the diggings. In the course of a few months, half the male population of Victoria had turned to gold-mining. Workshops and places of business were closed, farms were left short-handed, and ships lay deserted in the ports. Trade was at a standstill. The gold-fever was in the air and the infection was universal. Of the

70,000 inhabitants of South Australia no fewer than 20,000 swarmed into Victoria. In the meantime the news was travelling round the world.

Then in the summer of 1852 the flow of emigration from Europe began. Emigrant ships arrived at Hobson's Bay only to be deserted, even by their crews, as soon as they had dropped anchor. So large and so rapid was the influx of emigrants that special efforts had to be made to cope with it. Barracks were erected at Melbourne to afford temporary shelter to the newcomers, and several villages of tents arose on the outskirts of the town. In a couple of years Melbourne doubled in population.

As in America, so in Australia, there was a constant and unending stream of Argonauts between the ports and the diggings. But the Austral trail was neither so long nor so arduous, although both in Victoria and in New South Wales the great gold-beds lay beyond the Coast Range in districts in which there were no roads and human habitations were few and far between. These latter consisted for the most part of the squatters' homesteads, and their countless flocks provided a cheap and plentiful supply of animal food even when the rush to the gold-fields was at its height.

Fabulous stories were current of the wonderful finds at the diggings, and certainly numerous fine nuggets were unearthed. One of the largest was known as the "Welcome," and was found at Ballarat. It weighed 2,195 oz., and was sold at Melbourne for £9,325. The "Welcome Stranger," discovered near Dunolly, realized when smelted £9,534. The "Blanche Barkly," which hailed from near Kingower, was valued at £6,905. The glitter and fascination of the few prizes was in everybody's mind, the blanks were forgotten. Still on the whole the earnings of the Australian gold-diggers were fairly good. They fluctuated extremely,

of course, with the frequency or scarcity of rich finds, but seldom averaged less than £8 or £10 per week. The cost of living inevitably increased enormously. Prices, as compared with those of previous years, were quadrupled. Butcher-meat rose from 1*d.* or 2*d.* per pound to 6*d.*, in the autumn of 1852. The price of flour increased from twofold to threefold. Butter rose from 1*s.* or 1*s.* 6*d.* a pound to 4*s.* or even 5*s.* Garden produce for a time was even dearer: a cabbage early in 1854 cost 5*s.* Building materials during the height of the gold fever were at a premium. The wages of those workmen who remained at their trades increased on an average fivefold during the boom, and even after it was over, settled at double the original amount.*

Life on the Australian gold-fields, in the midst of the miscellaneous collection of humanity that had been attracted from all parts of the world, was full of excitement and adventure, and was not without its risks and hardships. Generally speaking, there were fewer outlaws and desperadoes to be found among the diggings of Ballarat or Bendigo than in the gulches of California. But the gold-lust and the passions it aroused, intensified by the orgies and debauches of the more dissipated diggers, and unchecked through the absence of legal and civic order unavoidable in such new and unorganized communities, inevitably led to turbulence and crime. Robbery and murder were not infrequent by bushrangers and others.

Although the Australian auriferous belt lay in a country less wild than that of California, and one perhaps less subject to climatic extremes, the Antipodean gold-seeker often had to undergo the severest hardships. The story of the Buckland River diggings is a case in

* This statement of prices and wages is based upon the tables given in the appendix to Tooke's "History of Prices."

point. Rich placers were located early in the year 1854 in the deep ravine of the Buckland. The steep hillsides rose wall-like round the winding river flat. It was autumn in Australia, though spring in England. There was hardly a breath of air in the ravine, which under the scorching sun was like an oven, while at night the temperature fell to a piercing cold. Hundreds of adventurers had as usual flocked to the diggings on the first news of a rich "strike." The gold placers lay in the bed of the river, and the miners worked up to their waists in water tormented by clouds of flies. But this was not all. A peculiar type of typhoid fever was endemic. Bad diet and want of vegetables aggravated the diseases and intensified the discomforts of the place. Physic, like vegetables, reached prohibitive prices, and certain pills which shall be nameless sold in reality at "a guinea a box." The Buckland River was a valley of death. "Constitutions that had borne the hardships of other fields broke down here," wrote an eye-witness, "and hundreds have perished, dying unattended and unknown. The little levels between the stream and the base of the mountain wall, for ten miles along the valley, are so thickly studded with graves that the river appears to run through a churchyard." Some left the diggings, thinking that even gold could be purchased too dearly. Many remained to take their chance of fortune or death, and sometimes found both.

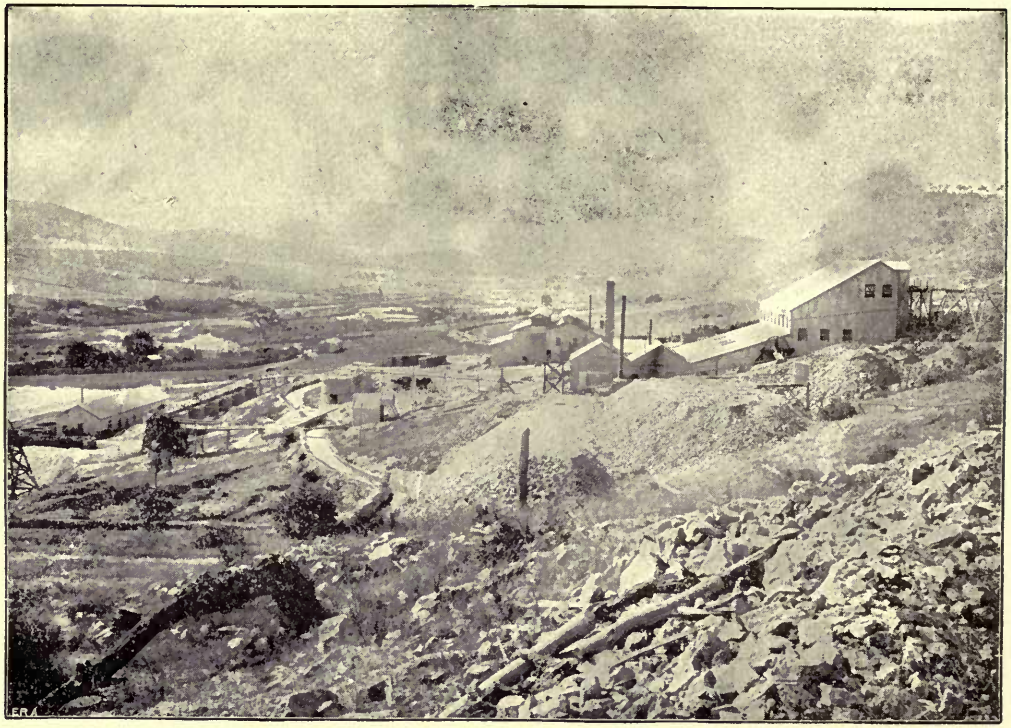
As in all newly discovered gold-fields, the more recent gold-bearing drifts that lay on the surface were first worked by shallow or surface mining. But as these gradually became exhausted or were worked out, the deeper and older auriferous drift was reached and worked by deep-sinking. This lower drift usually fills the hollows of old river-courses, which are called leads. They occur at Ballarat as well as in the neighbourhood of the Macquarie River. In the Macquarie valley the

gold-bearing drift fills a large part of the ancient channel of the river, which now occupies quite a minor bed on the surface of the drift.

With the working out of the surface deposits came, as in California, the prospecting for and working of auriferous quartz reefs. The opening up of quartz-mines involved the use of plant and machinery and the introduction of capital. Once again the capitalist came upon the scene, then the picturesque figure of the gold-digger with his " billy " and his " swag," and his pan or cradle, vanished from the scene, and set out for fresh fields and pastures new, or disappeared up country prospecting or " fossicking "—a lonely, adventurous, and restless figure, with the *wanderlust* in his blood.

The gold-mining industries of the Australian colonies proceeded to develop each on its own lines. In New South Wales, as in California, the production of gold reached its maximum in the early days of the placer diggings. The yellow metal is widely distributed through the highlands. Gold-mines are numerous and scattered, but individually they are, with the exception of a few mines like the Gibraltar of Adelong, small and of no great depth. A large proportion of the New South Wales gold yield is procured, as we shall see, by hydraulic sluicing and dredging.

In Victoria, on the other hand, the history of the production of gold was quite different, the yield having grown steadily larger since 1855. There are numerous auriferous quartz reefs, many of which are productive to a very great depth, and consequently quartz-mining has reached a high stage of development in this colony. In the Bendigo district alone there are 14 mines with shafts over 2,500 feet deep, and 8 which touch the 3,000-foot line. In the Lazarus Mine the great depth of 3,424 feet has been reached, while even this is exceeded by the 3,750 feet of the Victoria Mine. The



GIBRALTAR MINE, ADELONG, NEW SOUTH WALES.

South Star Mine at Ballarat is, too, fairly deep, bottom being touched at 2,520 feet, or nearly half a mile.

The production of gold from the Victorian mines has been large and fairly steady. In the fifty-four years from 1851, when gold was first found, to 1905, this colony produced gold to the value of £273,000,000, or more than half the total Australian output of £460,000,000 during the same period. In 1905 the product was £3,138,000.

The world's production of gold, which in 1849 was estimated to be of the value of six millions sterling, had in 1853, only four years later, owing to the immense alluvial finds in California and Australia, reached the enormous aggregate of £30,000,000. We know that the abnormal productivity of the diggings of the "fifties" was but short-lived, and it is not surprising to find that the high level of 1853 was not maintained. There was, as a matter of fact, a slow but steady diminution in the gold output, a shrinkage which lasted for just thirty years, and which in face of the increasing demands of commerce and the arts was beginning to cause serious misgivings to statesmen and financiers, when the tide of gold, which had been ebbing for so long, turned and began at last to flow.

CHAPTER IV

THE WORLD'S GREAT GOLD-MINES

FROM the year 1883, the world's production of gold, which had been steadily declining from the record output of the "fifties," began slowly to increase, owing very largely to the phenomenal productivity of one Australian mine—the Mount Morgan of Queensland. The discovery of gold in Queensland belongs to a later date than that of either Victoria or New South Wales, but, thanks chiefly to the Mount Morgan—one of the world's most wonderful gold-mines—the first named colony rapidly came to the front as a gold-producing country. According to some experts the rich mineral belt lying to the east of the colony is not even yet fully developed or prospected.

A great part of this belt is covered with a dense forest of gum trees. From the tree-tops king parrots look down on stray Chinamen prospecting the dry river-beds during the Queensland summer. Once in a while a white "fossicker" appears and sets up his tent for a few days beside the nearest waterhole. The up-country traveller will often come across a solitary gold-seeker,

busily at work in the bush under the ardent sub-tropical sun, cheerfully wielding pick or cradle, or patiently turning the primitive windlass which stands over his little shaft.

Gold was first found in Queensland at Gympie, some hundred miles north of Brisbane, in 1867. Gympie marks the southward limit of the mineral belt. This flourishing mining town occupies a beautiful site on the wooded slopes of the hills. The greater part of the inhabitants are directly interested in the gold-mining industry. Many of the original mines, after prosperous careers, are worked out; but others have been opened up from time to time.

The occurrence of the gold on the Gympie field is most peculiar. Several parallel slate-beds, dipping at a slight angle, traverse the district. In the opposite direction, and sloping at a much steeper angle, is a series of well-defined white quartz reefs. These reefs carry no gold, except where they cut through the slate-beds, but at those points the precious metal is invariably found not only in profitable, but in visible quantities. So common a feature indeed is visible gold at Gympie, that each mine is provided with a strong box, which from time to time becomes filled with particularly rich and nuggety specimens.

Mount Morgan, then a nameless hill in the Queensland bush, was a portion of a "selection" owned by a man named Gordon. The pasturage in this hilly up-country district was very poor, so that Gordon, with his few head of cattle, made but a precarious livelihood. In July 1882, two brothers, Ned and Tom Morgan, prospectors of considerable experience, happened to be "fossicking" in the neighbourhood. After some heavy rain they noticed indications in the wet rocks which seemed promising. Taking away a few samples they had them tested, and were amazed to find that the

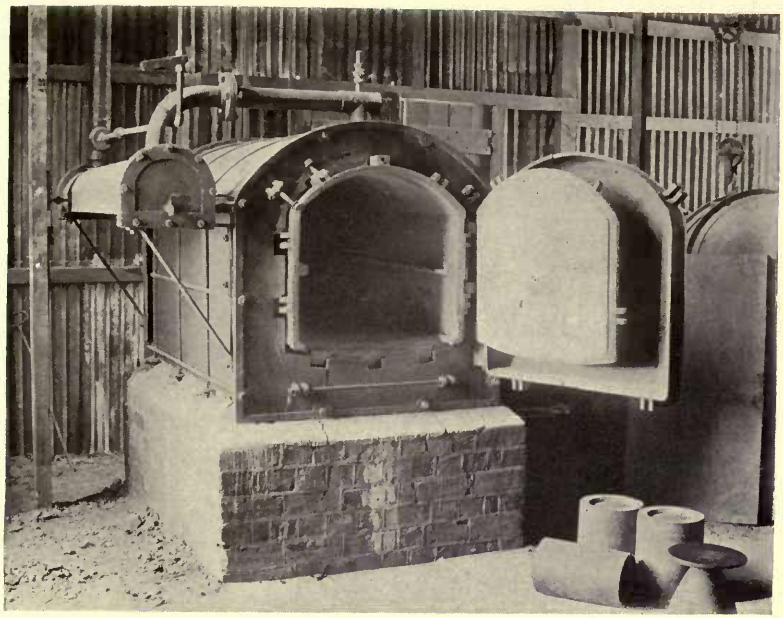
assay value of the stone was estimated at 3,700 oz. of gold to the ton. Returning to the scene of their wonderful discovery, they found Gordon quite willing to dispose of his selection of 640 acres for the mere bagatelle of £1 per acre. The Morgans did not then realize the value and extent of their new acquisition, but they were convinced that they had " struck it rich." Messrs. D'Arcy, Hall, Pattison, and a few others were let into the secret, machinery was bought, and active mining operations were begun. In a comparatively short time all concerned in the venture were millionaires.

Concerning poor Gordon's feelings and ultimate fate, history is silent. In the whole story of the gold-mines there is probably no more dramatic instance of the missing of a fortune beyond the dreams of avarice. The late Brunton Stephens, the Australian poet, has treated the theme in his poem " The Lost Chance ":

" Just to miss it by a hair-breadth—nay, not to miss it ! to have held it
In my hand, and ofttimes through my fingers run the swarthy ore,
Minus only the poor trick of art or science that compelled it
To unveil for others' good the hidden value, and to pour
On a thousand hearts the light of hope that shines for me no more."

It was very soon realized that Mount Morgan, which was one of a chain of low bush-covered hills, between 20 and 30 miles from Rockhampton, Queensland, was a huge gold-mine of unique character and phenomenal richness. Further working and investigation served to emphasize the fact that the Mount Morgan was one of the most wonderful mines the world has ever seen, a veritable hill of gold.

The summit of the hill, when opened out, proved to be a mass of siliceous brown hæmatite ironstone. Some of it was aflame with crimson tints, fading down to palish pink. For the rest—it had a frothy appearance, and it was light, like pumice-stone. The beautiful



Wernher, Beit & Co.

SMELTING FURNACE, CITY AND SUBURBAN MINE.

Wernher, Beit & Co.

CYANIDE AND SLIMES WORKS, CITY AND SUBURBAN MINE.

colouring of the iron pyrites earned for it the name of Peacock Ore. Throughout the whole mass, gold, unusually pure and free from alloy, was found in the most minute particles, rarely visible to the naked eye, but in a proportion decidedly profitable. Quarries lower down the hillside revealed a greater complexity in the deposited mass, but gold was still present in very similar proportion. The sides of the hill spread out and formed a shell of non-goldbearing rock, down the centre of which the great patch of gold ore continued.

How, it may be asked, did this great mass of gold-bearing material come to appear in such a unique form? After exhaustive investigations geologists have come to the conclusion that Mount Morgan is the result of aqueous action, such as might result from the upward flow of mineralized solutions, by which the deposited portions of a large mundic lode beneath the surface have been carried upward. The picturesque notion of a magnificent prehistoric geyser spouting gold in solution has had to be abandoned. That which appears to be siliceous pumice-stone, or tufa of geyser origin, is really the siliceous skeleton from which granular iron pyrites have been dissolved out by natural action.

For several years after its discovery, the Mount Morgan Mine was worked by a private syndicate on a comparatively small scale. In 1886 the concern was floated as a limited liability company with a capital of a million sterling. The ore on the summit of the hill was of phenomenal richness, and for a time the returns were abnormal—the £1 shares rising to £17 5*s*. Then when poorer ore was reached the price dropped, but as the steadily profitable nature of the lower-grade ore was realized a gradual appreciation in the shares took place. Numerous shafts were soon sunk into the heart of the hill, and exploratory drifts have been driven in different directions.

Thirty years ago the district was a solitude; now the valley below is a flourishing town. Nearly the whole of Mount Morgan has been quarried away, and the sides of the hill are covered with machinery. An almost perpetual cloud of smoke hangs over the scene, rising from the numerous furnaces, and at night the mount resembles a volcano belching forth flames and smoke from a hundred fissures.

The Mount Morgan Mine was one of the largest gold-mines in the world, at one time giving employment to more than 3,000 men. It was furnished with a complete equipment of the most perfect modern machinery. For several years after the opening of the mine almost every known method of gold-extraction was tried on the ore, but none were completely successful. The particles of gold were so excessively minute and so frequently coated with foreign matter that the usual modes of treatment were comparatively useless. Eventually, a modification of the chlorination process was tried, and proved very successful. From the beginning the principal alloy present in Mount Morgan gold has been copper, from which the gold is separated by a special electrolytic process; and now, after a period of marvellous productivity as one of the chief gold-mines of the world, Mount Morgan is slowly but surely changing as regards its principal product and has become simply one of the leading *copper* mines of Australia. As a result the gold yield of Queensland is at present declining. In 1905 it was £2,489,000.

Another gold-field which began to attract attention with the adoption of modern mining methods in the early "eighties" of the nineteenth century was the Kolar gold-field of Mysore in southern India.

It is a matter of common knowledge that gold has been found in India from a very remote period. More than twenty centuries ago the Indian satrapy was,

according to Herodotus, the only province whose tribute to Darius, the Persian conqueror, was paid in gold. But from the time of Pliny to the beginning of the nineteenth century, with the exception of Sir John Mandeville's legendary gold-digging ants, the gold-mines of India vanish from written history. Gold was probably found, as it is to-day, in limited quantities in the alluvial sands of the Himalayan and other rivers. There are traces of ancient workings in Hyderabad, and in the Wynaad district of Madras. The Indian demand for gold has almost always been greater than the native supply, and one mediæval writer refers to India as " the sink of gold."

By far the most important sources of the gold supply of India have been and still are the mines of the Kolar field in the native State of Mysore. In 1802 Lieutenant Warren, of H.M. 33rd Regiment, hearing of discoveries of gold, visited Wurigam (Ooregum), but with little result. About 1860 a Bangalore syndicate obtained a concession, but soon abandoned operations. But the pioneer of the existing Kolar mines was undoubtedly M. F. Lavelle, an old Irish soldier who began to prospect the ancient workings in 1871, and parted with his concession to a small syndicate five years later. Although practical miners were brought over from Australia, the results were disappointing. The gold of the upper strata of the reef had been completely exhausted by the ancients.

The period during which the ancient Kolar mines were worked is uncertain. Evidently the old-time gold-seekers prospected until they came upon traces of a chute of rich ore. This they proceeded to work with the primitive tools of the time, down to a depth of 150 or even 200 feet. The method adopted to facilitate the excavation of the ore was to heat it by fire and then chill it suddenly by throwing water on it.

This process rendered the ore more friable and easily worked, and it was slowly removed by being pounded with pieces of harder rock.

A problem that must have been found difficult of solution was to get rid of the inflow of water which would be encountered in depth. It is supposed that large gangs of men must have been continuously employed in baling the water and passing it up in vessels to the surface. In support of this theory it may be mentioned that hundreds of old vessels have been found in the ancient workings of the Coromandel Mine, while series of niches, evidently intended for the feet of the workers (who formed a sort of human ladder passing the vessels from hand to hand), were cut in the walls of the shafts. A recent visitor to the Kolar gold-fields writes: "We were standing in a drive 200 feet below the surface, and close by, the blasting had exposed a section of an old stope, the deepest part of the ancient workings on that particular chute. I would have explored this to see for myself some of the relics referred to, but I found that the breadth of the stope, which had been big enough to enable the ancients to work in, and to hammer the quartz to pieces, was not wide enough to contain my body."*

During the years 1879–1880 some minor discoveries of gold-bearing ore were made. On this slender foundation several mining companies were floated in London, and a boom ensued. Dark days followed, and it seemed in 1883 as if the Kolar field would have to be abandoned as a failure. At the office of the Mysore Company there still hangs a transfer of 2000 shares at the absurd price of 9*d.* and dated 1883—shares that have for years been worth as many pounds as they then sold for pence! At a memorable meeting held on October 5, 1883, more optimistic counsels prevailed,

* Curle's "Gold Mines of the World," Ch. IV. pp. 119–20.

and one of the leaders of what was then considered a forlorn hope had in later years the satisfaction of receiving a cup made of 50 oz. of gold from this mine. The early days of the Kolar field afford a striking contrast to the history of most other gold-fields, where the first comers usually made the richest finds.

The Kolar district possesses few features of interest beyond the gold-mines, which lie at an elevation of about 2,800 feet above sea level. The horizon is bounded by the outlines of blue and distant mountains, but the immediate neighbourhood consists of an undulating, tree-dotted expanse—uncultivated land for the most part—presenting an unpleasing contrast to the luxurious vegetation of the lower-lying parts of Southern India passed on the way up from the coast.

The gold-field is connected with the Madras-Bangalore railway line, and can be reached from Madras in twelve hours and Bombay in forty. The three or four miles in the middle of the reef presents almost as busy a scene as a similar section of the South African Rand, but the substantial stone chimneys and red-tiled roofs of the mining premises offer a pleasing contrast to the unlovely smoke-stacks and eternal corrugated iron of the mines round about Johannesburg.

Geologists tell us that the Kolar reefs are found in a bed of schistose rock about 15 miles long. In the centre this bed is from 3 to 4 miles broad, but towards each end it tapers off and finally disappears. This bed of schist is entirely surrounded by granite, so that the area of the field is very clearly defined. It appears to be fairly certain that the main or Champion lode is a fissure vein. Although cut up by dykes and faults, it holds its course with great regularity and probably averages a width of four feet throughout.

The climate in this elevated portion of Mysore is

fairly good, but Europeans run some risk from the epidemics of cholera and small-pox which appear among the native workmen from time to time. Many of the white miners, who number about 1,000, are Italians, who go out to India on contract at the rate of £6 or £8 per month. Native labour is plentiful—about 30,000 coolies being employed in or about the mines—and is apparently cheap, the average coolie receiving only from 5*d.* to 8*d.* per day ; but the ordinary hammer or stope native does not get through half the work of a Rand Kaffir, and to secure even this, close supervision is needed.

The Kolar mines are all timbered, the props being brought mostly from Calicut. Coal is an expensive item, having to be brought all the way from Bengal, Australia, or even England; but the Cauvery River, nearly 100 miles away, has been harnessed to provide electric power. The surface water supply is rather scanty, while, on the other hand, the workings are sometimes flooded to a great depth.

The gold-mines of the Kolar district are worked under leases from the Mysore Government, which secure to the State a royalty of 5 per cent. on the gold produced. The total product of this field in modern times has been estimated to have reached, up to the end of 1911, some £30,000,000 sterling in value.

The output of the Indian mines formed in itself no great proportion of the world's supplies, but the reopening of the ancient Kolar field was typical of the success of modern scientific methods, by means of which auriferous deposits hitherto neglected can be worked with profit. The reorganization of gold-mining on modern lines, which began in the " eighties," speedily developed into a revolution in face of the unparalleled discoveries in South Africa.

THE WORLD'S GREAT GOLD-MINES

South Africa

Of the later discoveries of gold, those of South Africa were destined to be the most important of modern times. There can be no doubt that the gold-mines of the Rand have exercised a most profound effect, not only upon the political and economic affairs of South Africa and of the British Empire, but also upon the world's supply of bullion.

The first recorded discovery of gold in South Africa during the nineteenth century was that made by Dr. Mann in 1864 in the plateau forming the watershed between the Rivers Lipalule and Limpopo. Dr. Mann also reported having seen numerous traces of ancient workings. It has since been proved that there is a series of ancient gold-mines, or workings, extending from north of the Zambesi to the Murchison Range in the Transvaal, and from the lower Sabi to Bechuanaland in the west. The old-time miners evidently used to work the reef outcrops as open quarries.

Previous to 1868, the Boer Government, evidently desirous of averting the social and economic unrest invariably attending the discovery of the yellow metal, prohibited gold-digging in the Transvaal. But repeated finds such as those of Edward Button's in the Sutherland Hills and in the Kleinletaba in 1869, and the Murchison Range in 1870, caused the repeal of the law against prospecting.

The Lydenburg fields are said to have been worked by the Portuguese in the seventeenth century, but were only rediscovered in 1869. Though lying at a height of nearly 5,000 feet above sea level, the diggings at Pilgrim's Rest and Mac Mac Creek are alluvial placers—the only rich alluvial beds in South Africa. The opening out of these diggings in 1876 led to an influx of gold-seekers from all parts of the world.

In Pilgrim's Rest Creek, which lies some 30 miles west of Lydenburg, the drift was originally from 5 to 12 feet deep. The upper strata was a fine alluvium, then came clay in which pebbles were embedded, and lowest of all, and resting on the solid rock, was the gold-bearing drift, averaging about a foot thick. The gold was present in grains and nuggets, most of which were rounded and coated with oxide of iron. Alluvial diggings were also worked at Mac Mac Creek, where the drift was made up of slaty sandstones. There were no boulders like those of Pilgrim's Rest, and the gold occurred in finer grains, though it was not of such good quality. The aggregate production of these diggings was not however very considerable.

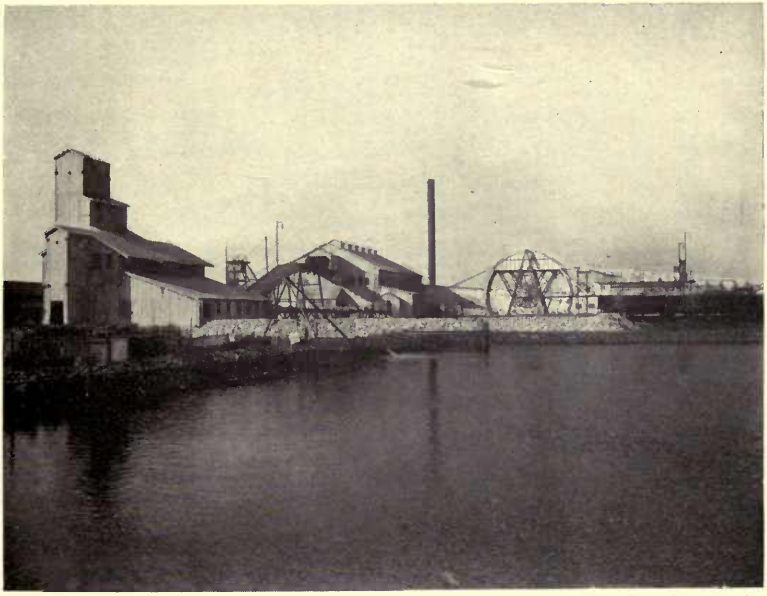
About the year 1884 reef gold was discovered in a number of places on Moodie's Mountain, and on the adjacent hills of the De Kaap Range, and a new quartz-mining field, with Barberton as its centre, sprang into being. From 1885 onwards a series of discoveries, chiefly of reefs of conglomerate formation, or "banket" as the Dutch called it, was made at Witwatersrand, Klerksdorp, Potchefstroom, and Heidelberg.

The Witwatersrand (White Water Ridge) deposits, destined to become world-famous, were located in 1885 by a man named Arnold working on the Langlaagte farm. Part of the district was proclaimed as public diggings on July 18, 1886. The usual rush followed, and the hitherto quiet and pastoral veld became a scene of bustling life and activity. A large, heterogeneous, and more or less picturesque collection of wagons, carts, and tents belonging to the various prospectors and gold-diggers, occupied the site of the present city of Johannesburg, which was laid out towards the end of 1886.

The reefs were at first mined by open cuttings on the outcrop, the ore being hoisted by windlass. But this

Wernher, Beit & Co.

THE COMPOUND, GLEN DEEP MINE.



Wernher, Beit & Co.

GENERAL VIEW, FERREIRA DEEP MINE.

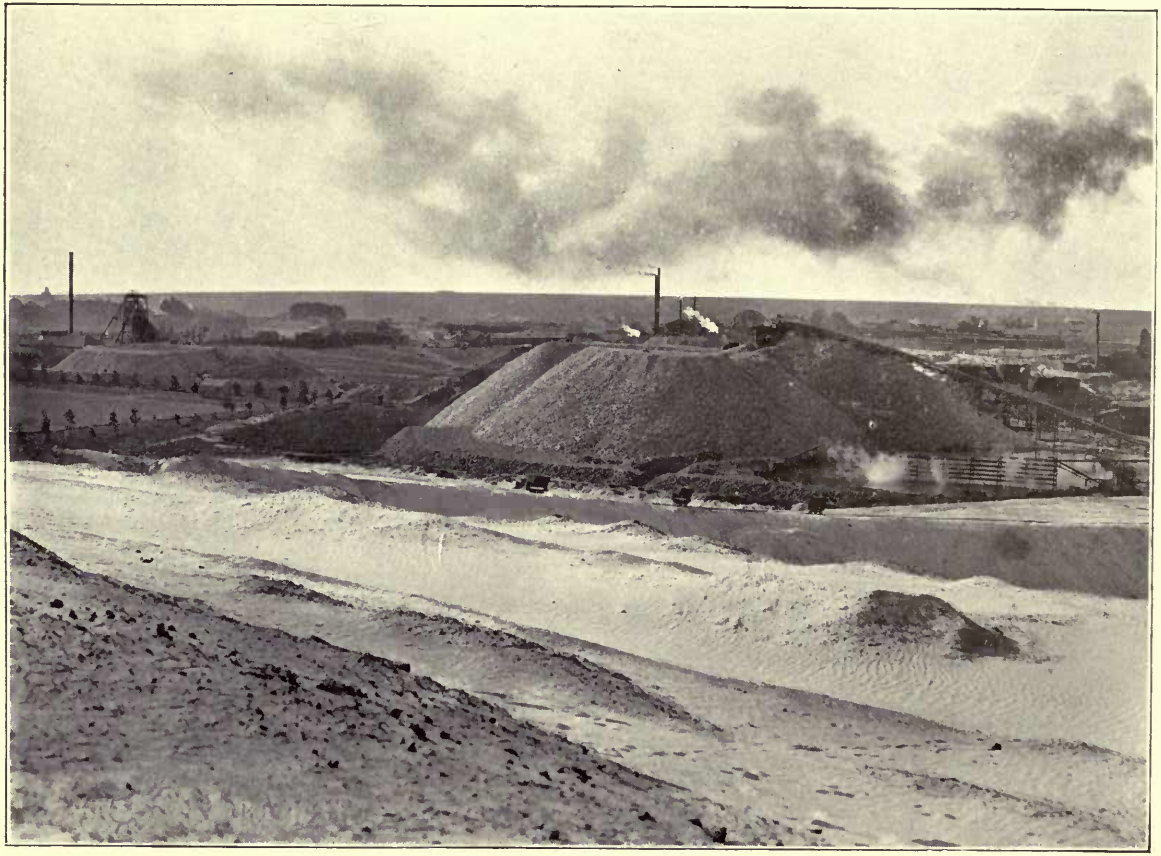
primitive method soon had to give place to others more effective. The "banket" reef required treatment similar to that of quartz, involving the employment of considerable plant and capital. There was little resemblance between even the early stages of mining on the Rand and the earlier days of the Californian or Australian diggings. The mining engineer took the place of the lone digger, and expensive machinery of the primitive cradle. Much gold had to be sunk before any was raised. In 1887 the total yield was only £81,022, but two years later it had increased to £1,300,509. By that time no fewer than 68 gold-mining companies had been formed on the Rand. A strong upward movement in prices followed, culminating in the boom of 1888–1889. This again was followed by a slump, but steadily increasing output and dividends more than restored confidence. The Witwatersrand, with its series of "banket" beds nearly 40 miles in length, unlimited apparently in depth, and payable over the greater part of its entire area, became the new Eldorado, and Johannesburg the greatest gold-mining centre in the world.

The Witwatersrand is a range of low hills, some 35 miles south of Pretoria, lying a little above the surrounding veld, which has an average height of nearly 6,000 feet above sea level, and forming the watershed between the Limpopo and the Vaal. The district is, for the most part, flat or gently undulating. There are no trees except those that have been planted. During the rainy season there is a growth of rank grass, but this dies away with the cold winds of the South African winter. Johannesburg itself—as befits the most populous city and commercial capital, not only of the Transvaal (now the greatest gold-producing country in the world), but of the whole of South Africa—is a handsome and well-laid-out modern city. On three

sides—south, east, and west—lie the gold-mines of the Rand, marked by tall chimney-stacks, head-gearing, battery-houses, and other erections and buildings of corrugated iron. The bare veld is dotted with these unlovely erections for a distance of over 50 miles, and on a working day the incessant din of the stamp batteries, and the fine white dust arising from the crushed ore, penetrate everywhere.

An indispensable annexe of the Rand gold-mine is the compound for the Kaffir labourers, each one of whom has to have a pass or permit to enter or remain in the district. The compounds generally consist of a range of corrugated iron buildings forming part of a large quadrangular enclosure. The population of Johannesburg in 1908 was 180,687, comprising 95,162 whites, 78,781 coloured natives, and 6,780 Asiatics. A railway traverses the whole length of the Rand, running westwards via Klerksdorp to Kimberley, and eastwards via Springs to Delagoa Bay. As showing how well situated Johannesburg is as the metropolis of the Rand, it may be said that the mines included within the muncipal area (82½ square miles) produce nearly half the total output of gold in the Transvaal. In fact, in 1899, before the Boer War, when 5,762 stamps were at work on the Rand and the total yield amounted to £15,134,000, no less than 80 per cent. of the output was got from within a radius of 12 miles from Johannesburg.

The gold-bearing reefs of the Rand are regularly stratified beds of conglomerate quartz pebbles in a sandstone matrix varying in thickness from a few inches to many feet. The yellow metal is found as a rule, not in the pebbles, but in the matrix. The conglomerate is cemented together with a mixture of silica (or lime) and sand, and a sprinkling of iron pyrites, which, being decomposed, causes the upper strata to be



Wernher, Beit & Co.

GENERAL VIEW, FRENCH RAND MINE.

UNIV. OF
CALIFORNIA

known as "black sands," and the lower (unoxidized) as "blue rock."

It is assumed by most geologists that the banket reefs, like other conglomerates, are marginal sea deposits. The quartz pebbles are the remains of rocks once washed by the waters of a prehistoric sea. In the gradual process of breaking up, their gold contents were scattered far and wide. After a time the detritus ceased to contain quartz or gold, and the auriferous bed was buried deep under other strata, and was cemented into a compact mass by pressure. Then by some means, some alteration of levels or change in the earth's crust, the "banket" reefs have been tilted up in a wonderfully uniform fashion. The famous Main Reef outcrops of the Rand are the upturned edges of this most compact of gold-bearing strata; and extend practically all the way from Roodeport on the west to Driefontein on the east, a distance of over 20 miles. The Main Reef series extends from Klipfontein to Randfontein, a distance of over 40 miles, and is said to stretch over 60 miles in all from east to west.

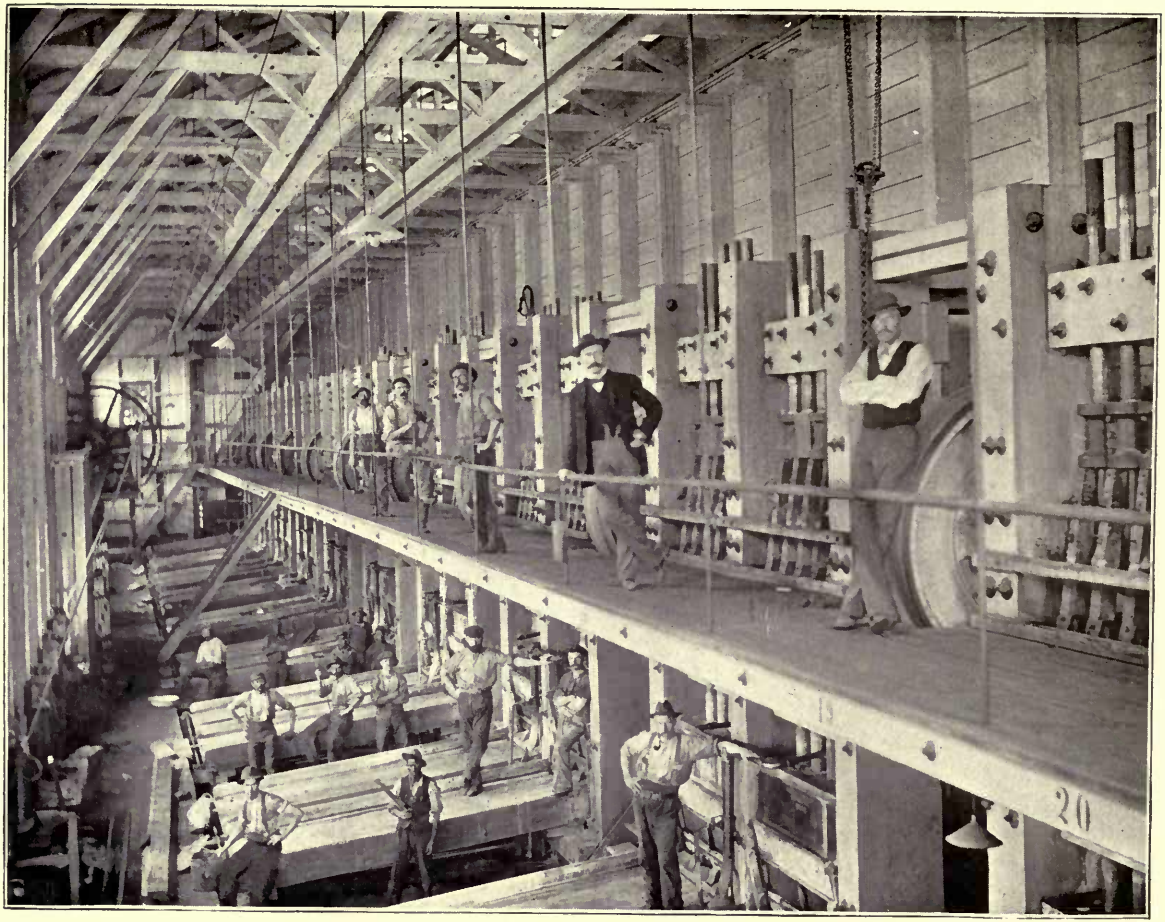
The distribution of gold in the Rand "banket" is much more regular and uniform than in most other auriferous deposits. This is clearly proved by the continuity of areas from which ore has been taken out of mines that have been worked for years.

In the opinion of experts some reefs are on the whole more valuable than others, but it is difficult to generalize, as the same reef may vary in value in different districts. Thus in the central section of the Rand, near Johannesburg, the Main Reef Leader and the South Reef have a high value, while the Main Reef itself is of a lower grade in gold production. In mines west of the Langlaagte Estate, the South Leader is the richest, the Main Reef Leader being irregular and the Main Reef poor; while in the east section of the gold-field the grade of the

South Reef deteriorates and the Main Reef becomes for once the most productive.

The gold-mines of the Rand are among the best equipped in the world, possessing the most modern and efficient machinery, both underground and on the surface, for the mining, milling, and treatment of large quantities of ore. The mechanical improvements have been introduced mainly with a view of reducing the cost of handling the ore and securing the separation of the low-grade waste material from the ore before milling. The adoption of economic methods in ore transportation and treatment have not only decreased costs, but have led to increased production. One of the latest innovations is the sand-filling of stopes. The ore is taken out and crushed, and after the gold is extracted the residue is put back into the workings. This allows the pillars of ore, which would otherwise be necessary to support the roof, to be removed, and dispenses with the unsightly heaps of "tailings."

The continuance of the gold-bearing "banket" reefs of the Rand to a great depth was at first unsuspected, and was only realized by degrees. About the year 1890, however, it came to be the generally accepted belief that, as these reefs had been deposited by the action of water, the particles of gold would be widely distributed, and there was every probability of the auriferous reef extending to a great depth. Boreholes were sunk on the dip of the Geldenhuis and Crown Deep Mines, and confirmed the opinions of the experts. As the reef dipped towards the south, it at once became evident that all land lying to the southward, which, except for the first thousand feet or so, had been considered as worthless, was almost certainly underlaid by the reef and therefore of great prospective value. These deep-level areas were promptly acquired by capitalists and proprietary syndicates.



Wernher, Beit & Co.

BATTERY, CROWN DEEP MINE.

CANCELLED

In January 1890 the May Deep Level shaft struck the reef. Very soon afterwards the Ecksteins (the local representatives of Wernher, Beit & Co.) and other financiers had acquired blocks of deep-level claims on the dip of the best outcrop properties, and thus laid the foundations of such gigantic corporations as the Rand Mines, Ltd., which was floated in 1892. This concern held 1800 claims, selected with considerable acumen, directly beneath several of the richest and least faulty outcrop mines. Boreholes were sunk, notably on the dip of the Geldenhuis and Crown Deep Mines, cutting the reef exactly where predicted. The Geldenhuis was the first deep-level mine to start work, but the returns were, at first, owing to the scarcity of labour and the crushing of unsorted ore, rather disappointing.

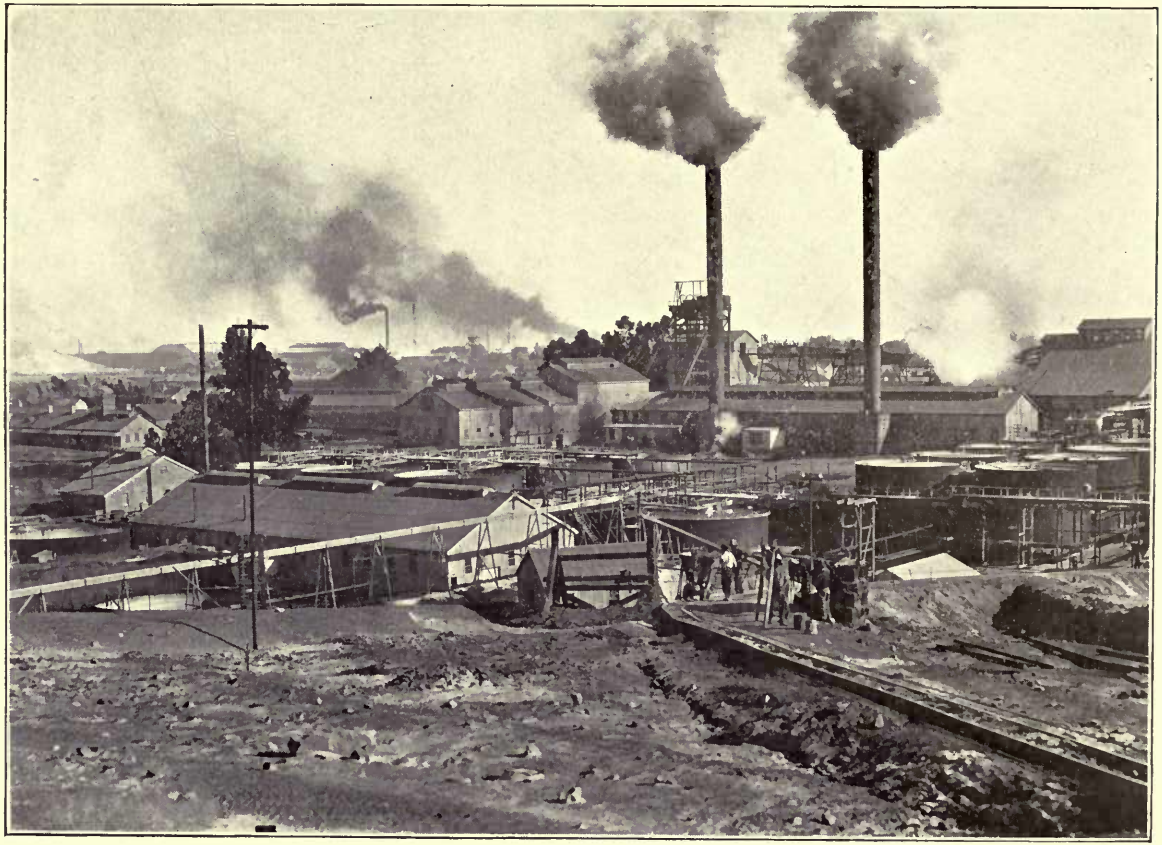
Nevertheless, several subsidiary deep-level mining companies, holding from 150 to 200 claims, and each with a capital of several hundreds of thousands of pounds, were floated. The capital expenditure necessary in deep-level mining on the Rand is very considerable, and it is not unusual for the directors of a deep-level mine to expend £500,000 before a single ton of ore is milled.

Before long the whole area of the Rand, which was thought to cover the reef even at the extreme limit of depth at which mining was practicable, was pegged out. More boreholes were sunk beyond the central and richest part of the Main Reef, cutting the lode in almost every instance, and still more companies were floated. In 1893 the deepest borehole sunk up to that time struck the reef a long distance below the then boundary of the Simmer and Jack Mine at a depth of 2,385 feet. As the engineers of the deep-level mines already in operation or projected, calculated that the reef would run out of their property at a depth of

2,000 feet, it at once became apparent that a second row of deep-level mines could be opened up to work the still deeper areas, which, however, owing to the flattening of the "banket" bed, lay within a practicable mining depth. The angle of dip observed near the outcrop varied from 45° to 70°, but was found to change as development proceeded downwards, until a very considerable flattening of the reef was observable in depth.

For the purpose of developing the deeper part of the reef by a second row of deep-level mines, the Gold Fields Deep Proprietary Co., Ltd., was formed, its finances being guaranteed by the Consolidated Gold Fields of South Africa, Ltd. The promoters of this great undertaking, which involved the sinking of millions of capital, were rewarded in 1895 by the finding of the reef on the dip of the Meyer and Charlton Mine in the centre of the Rand at the great depth of 3,251 feet. This was then the deepest borehole ever sunk in the Transvaal, and was held to prove that sufficient of the famous "banket" reef underlay the Rand to keep the mines employed for a generation to come. Since that time boreholes have been sunk to the immense depth of 5,500 feet, or more than a mile beneath the surface. In March 1899 there were no fewer than 47 deep-level mines at work on the Rand.

We have seen that the natural conditions on the Witwatersrand were distinctly favourable to deep-level operations. The chief obstacles to deep-level mining are usually: firstly, depreciation in value of the ore; secondly, dykes, faults, and broken ground; thirdly, water; and finally, heat or increasing temperature. The first impediment has been proved by practice to be non-existent on the Rand. As regards faults and dykes, although they are more frequent in the deep-level than in the outcrop mines, they are



Wernher, Beit & Co.

EXTRACTOR HOUSE AND SLIMES WORKS, VILLAGE DEEP MINE.

easily traced, and are not considered a serious factor. Thirdly, the Rand rock formation is so regular that very little water finds its way into the workings when once they have been pumped dry of the water tapped during the shaft-sinking. Finally, the increase in temperature is found by experiment to be not more than one degree in every 200 feet of depth, so that there is no reason why the heat in a formation of solid sandstone should debar mining operations at a depth of 6,000 feet. Some engineers go so far as to prophesy that, with improved ventilation, a depth of from 10,000 to 12,000 feet will ultimately be reached.

The Transvaal is already one of the greatest gold-producing countries the world has ever known. The output in 1905 was valued at £20,802,074, and in 1909 it had reached the great total of £30,925,788. In the short space of less than a quarter of a century, from the finding of the precious metal until the end of the year 1909, the value of the gold produced has reached the immense aggregate of £246,000,000.

As to the future of gold-mining on the Rand, experts agree that it has every prospect of being a rosy one. The regularity in value of the gold-bearing reefs has proved to be so reliable that mining engineers can only forecast their probable value by the limit in depth of practical mining. In 1904 Mr. Lionel Philips pointed out that the Main Reef series had been proved for over 60 miles, and he ventured to estimate the prospective value of the gold-contents of the ore yet to be mined at the stupendous sum of £2,500,000,000, a total which beggars the imagination and is only conceivable when it is said that it will keep the Rand mines busy for nearly a century to come.

The De Kaap gold-field, of which Barberton is the centre, lies 200 miles east of the Witwatersrand, on the borders of Swaziland. It is a shallow, basin-like valley,

surrounded by steep mountains. The rich patches of ore found in the district originally in 1875 did not attract attention until 1884–1885. That on the site of the Sheba Mine attracted capitalists, and in 1886 a "boom" ensued. In those days the journey to this picturesque mining district was usually made by wagon from Natal, and occupied about two months.

The reefs, some of quartz, others, like the Sheba, of quartzite, are quite different from those of the Rand. The base is coarse granite. They run through the mountains, all along the eastern escarpment of the ranges, with remarkable regularity, cropping out here and there in rich auriferous patches, which, however, rarely continue in depth. The lodes are easily opened up by horizontal adits.

The history of the Sheba Mine shows it to have been at one time one of the first rank. This mine, briefly, consists of a wide reef of quartzite, dipping at an angle of 45°, and carrying one main chute of rich ore which has been proved to continue down to a depth of 1,500 feet. In many places the chute ore has been of exceptional richness, but the value of the product has been very irregular. In the upper levels practically all the rich ore has been worked out. The output of the De Kaap field, which in 1896 was 121,000 oz., had by the year 1905 diminished to 43,000 oz.—little more than one-third.

That part of South Africa which we know as Rhodesia has long been famous for its ancient gold-workings, and in these latter days is again coming to the fore as a gold-producing country. The works of Theodore Bent and Dr. Carl Peters, and also Sir H. Rider Haggard's sensational novel "King Solomon's Mines," have all helped to popularize the theory of South Africa being the ancient Ophir. But the later and more scientific researches of Mr. Randall McIver, first an-

nounced at the South African meeting of the British Association in 1905, and later communicated to the Royal Geographical Society, have proved that such ruins as those of Zimbabwe, which are apparently contemporaneous with the mine workings, are simply the remains of the huge kraals of earlier generations of natives, and are not more than 300 or 400 years old.

Whichever theory is true, and whatever the age of the workings, these latter have proved a very reliable guide to the modern prospector and mining engineer. The old-time gold-seekers never wasted much energy or labour on the barren reefs which so closely resemble the gold-bearing veins and are found outcropping all over the country. In some instances the ancient workings continue in an almost unbroken line of from 1500 to 2,000 feet in length, and in such cases a wide and profitable chute of gold is almost invariably found. So reliable are these indications, in fact, that many modern mines such as the Globe and Phœnix, Geelong, Selukwe and Bonsor, have been sunk on the strength of such evidence, and with good results. The precious metal occurs disseminated in quartz throughout the sedimentary rocks into which the granite intrudes, and in quartz veins traversing them. The deposits of gold are all situated close to the granite contact. The reefs are usually rather wide and easily broken.

The gold-mining district of Gwanda lies about 100 miles south-east of Buluwayo, whence the coach road runs through the Matoppo Hills, the scene of many a fierce fight during the Matabele rebellion. Round about Gwanda there is thick bush, which provides fuel for the mining machinery, though not far distant is the Tuli coal-field. The Mopani wood yields excellent mining timber, and several rivers afford a good water supply. The Gwanda reefs are of fair thickness, and carry a good and regular proportion of gold. The

Geelong is one of the principal mines in the district. It lies on a hill in the very heart of the bush, and not so very long ago the roar of lions might have been heard not far distant from the radiance of its electric lights. Water has to be pumped from nearly four miles away. The Geelong reef is of plain, almost white quartz. It averages 15 feet thick, and gold is apparently present throughout the mass. The reef, which dips at an angle of 30°, had been worked by the natives down to a depth of 250 feet.

No account of the history of gold-mining in Africa, however brief, would be complete without some mention of that part of the West or Gold Coast which has, from time immemorial, been associated with supplies of the noble metal. Herodotus tells us that the Carthaginians received gold from a black people who traded for it with the wild tribes of the west coast. West Africa was one of the first sources of the limited gold-supply of mediæval Europe. The Portuguese began to exploit the Gold Coast in the fifteenth century, and reached one place which they called "Sâo Jorge da Mina," the present Elmina. English, French, and Dutch adventurers hastened to share the spoils.

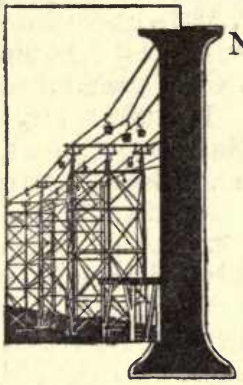
For a long period the auriferous richness of the region seems to have been lost sight of. Burton, in his "Wanderings in West Africa" (1862), was one of the first to redirect attention to it. "The whole land is impregnated with the precious metal," he wrote. "I find it richer in sedimentary gold than California in 1859." Later prospectors admit that gold is found in almost every part of West Africa, but only in a few districts in paying quantities. The auriferous beds have long been worked by the natives—those on the river banks or sea shore by washing with a wooden platter, and the deeper deposits by means of primitive pits, up which the "pay-dirt" was hoisted in calabashes.

The richness of the Tarkwa main reef was demonstrated by M. J. Bonnat, a French trader, about the year 1880. Transport difficulties were at first considered to be insuperable obstacles to commercial exploitation of the Tarkwa reefs. Largely owing to the great promise of the gold-field, however, a railway was constructed. A number of concessions were taken up, and a concessions ordinance was promulgated in 1900. In the following year no fewer than 2,825 concessions were granted, and there was a boom in the West African market on 'Change. Many concessions were abandoned and the inevitable " slump " followed. In 1902 a large gold-mining company began practical mining operations, and since then the output of gold has gradually risen until in 1907 it had reached a total of 292,125 oz., valued at £1,164,676. One of the principal West African mines is at Obuassi in Ashanti. The labour underground is performed principally by Basas and Krumen from Liberia. The Apollonia are, however, said to make the best miners, having carried on the old workings from Portuguese times.

In following the story of the gold-mines during many centuries and in many lands, great general advances in method will doubtless have been noted. But in order accurately to gauge the progress that has been made, and to contrast the new with the old order of things, it will be necessary to try to gain a clearer insight into the rationale of modern gold-mining, to understand what a modern gold-mine really is like, how it is worked, how the ore is treated, and the numerous and complicated processes that are often required before mother earth can be made to give up the coveted gold.

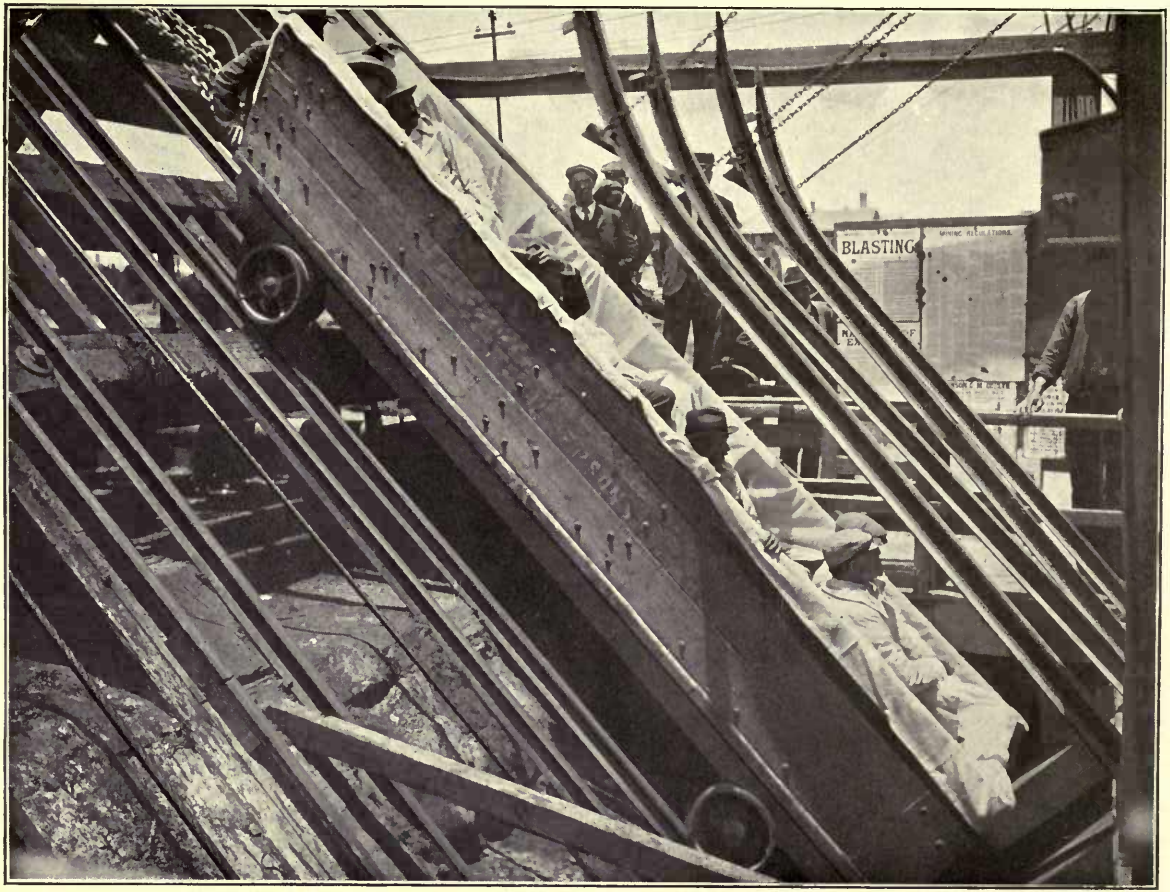
CHAPTER V

MODERN GOLD-MINING



IN following the story of the gold-mines from the earliest period down to modern times, the reader will doubtless have been able to trace their gradual evolution from the most primitive alluvial washings, and the most rudimentary diggings, together with the simultaneous and progressive improvement of appliances and implements. As I have endeavoured to show, the pan, the cradle or rocker, the Long Tom, and the sluice, indicate and represent successive stages in the evolution of contrivances in use in alluvial gold-fields. The gold-mine proper—the underground working of gold-bearing veins (or lodes) and reefs—has naturally developed on quite distinct lines. The gold-mine of to-day is a huge undertaking, and modern gold-mining and gold recovery form a highly specialized and scientific industry. It may be of interest therefore to deal with this phase of the subject in some detail and to trace the working of a modern gold-mine and of practical gold-mining—including the treatment of the ore and the separation of the precious metal—from the very beginning.

When a gold-bearing reef has been located by prospecting or otherwise, and it has been proved by the sinking of boreholes that the promise of the outcrop



Wernher, Beit & Co.

DESCENDING ROBINSON GOLD-MINE.

UNIV. OF
CALIFORNIA

or upper strata holds good in depth, the lode is opened up by means of a vertical or an inclined shaft, or by a horizontal adit or gallery. If the dip of the lode is steep, the shaft should be vertical, but if the reef only dips gently an inclined shaft is often used. The working of a mine by an adit is much more economical than by means of a shaft, as it saves pumping and winding, but it is of course only practicable in hilly country. Where the ore deposit lies below the general level, it must be worked by a shaft. The inclined shaft is a more rapid and economical method of development for inclined reefs than the vertical shaft, and it has the additional advantage that information as to the value of the deposit is gained as the shaft is sunk. Vertical shafts, on the other hand, are better adapted for rapid hoisting, and allow of a greater output of ore than inclined shafts. The headgear of the shafts are prominent features of every mining district.

As the shaft is sunk deeper and deeper, cross-cuts are excavated to the reef, and galleries or passages, called "levels," are driven at intervals along the lode or reef. These parallel levels, which form later the main haulage roads, are connected for purposes of ventilation by small vertical shafts, called winzes. In metalliferous mining the levels are driven closer together than in coal-mining. There are no noxious gases as in collieries, but in deep workings ventilation is important, as also is the drainage, and in most gold-mines powerful pumps are constantly at work. In a well-managed mine, working a reef of varying productivity, the work of development and exploration is kept well in advance, so as to ensure a regular output, and it is no unusual thing to have enough payable ore in sight between the levels to provide for two or three years' working.

When the development of a gold-mine is sufficiently

advanced the actual working or extraction of the ore begins. We have seen that the bodies of ore to be worked are blocked out in rectangular areas bounded above and below by levels, and on each side by shafts or winzes. The ore body is then attacked by "stoping." The working faces where the ore is actually excavated are called "stopes" or steps. The stoping, or breaking down of the ore, may be either underhand or overhand. Underhand stopes may be compared to a man working on a flight of steps and cutting away step by step from under his feet, and overhand stopes to the way in which a man may stand, say, on the cellar steps and cut down the flight of steps over his head.

SECTION OF STOPES IN A MINE.

Wernher, Beit & Co.

UNDERGROUND : CITY DEEP MINE.

UNIV. OF
CALIFORNIA

The actual excavation of the gold-bearing rock is carried out by means of rock-drills, either rotatory or percussive, worked by compressed air, and followed by the use of an explosive—generally dynamite, fired by electricity. In the Rand mines, the moving of the broken ore from the stope-faces to the loading-shoots at the level below, if the gradient is not steep enough to allow it to slide down, is effected by Kaffirs with shovels. Then it is loaded into tip-wagons, trundled to the shaft bottom, and hoisted to the surface.

When all the available ore has been extracted the walls or sides of the lode have to be supported. If there is not enough debris to do this, timbering has to be resorted to, or if the lode be very wide, like the famous Comstock Lode, rubbish is lowered from the surface to fill up the disused workings and so prevent the walls caving in. In some gold-mines sand is used to complete the filling up of the worked-out stopes.

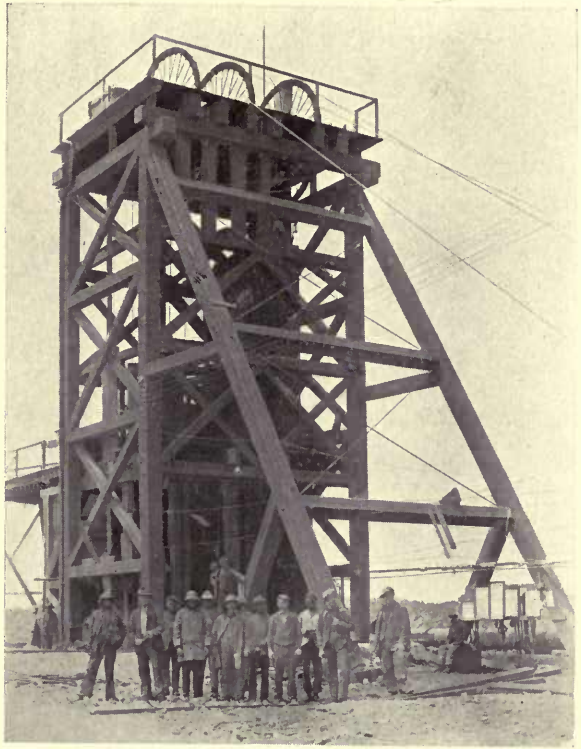
In the deep-level gold-mines on the Rand it has been found advisable to have two or more shafts. On the Amalgamated Simmer and Jack properties no fewer than ten shafts have been sunk for purposes of development and ore-raising. At first most of the Rand mines were worked by means of vertical shafts, but the fact that below the level of 800 feet the angle of dip of the reef rarely exceeded 32° led to a revolution in the location and sinking of outcrop mines. Latterly the majority of the mines have been worked by main inclined shafts, a system which has been found to effect a decided economy in time and expense. In many cases inclined shafts are used from the surface, and although in deep-level mines vertical shafts are inevitable, when they strike the reef they follow its course and become inclined shafts.

When the gold-bearing ore is brought up the shaft

in wagons or trams, these are run off and tipped over "grizzleys" or screens which separate the fine material from the coarse. The former passes through directly into a huge bin, while the latter runs down the screen to a sorting floor or table. The larger pieces of ore are taken to the rock-breaking machines to be broken up, whence finally the broken ore is taken in trams or wagons to the stamp-batteries to be crushed.

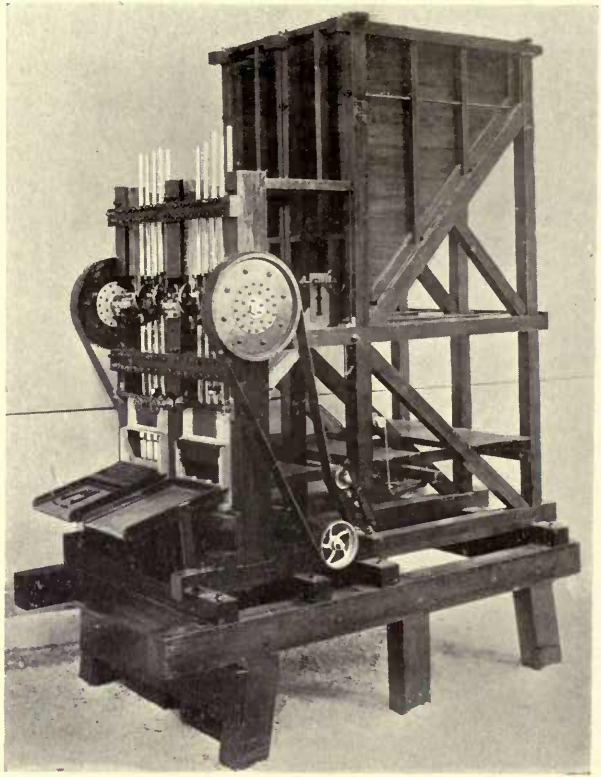
The sorting of the gangue or ore is very necessary in the case of a narrow reef, say from one to two feet thick. A drift or passage of at least 2½ to 4 feet in width has to be blasted, and as a result a good deal of barren rock is mixed with the ore. Obviously it saves a good deal of expense and wear-and-tear to battery-stamps, if as much as possible of the worthless rock is picked out. Of late years ore-sorting has made great strides on the Rand. Large revolving tables and belts have been erected. Over these the rock, after sliding down the grizzleys or screens, slowly passes. Streams of water play upon it, cleansing it and showing clearly to the sorters which is ore and which is waste. At some mines 20 to 30 and even 40 per cent. of the whole quantity is sorted out as being valueless. The mines employing this careful system of sorting are distinguished by their better comparative profits and their high yield of gold per ton of ore crushed. But it should be remembered that every ton of waste rock rejected increases the total working costs.

One of the most difficult and important problems the gold-miner has to solve is how to separate the yellow metal from the ore in which it is interned. Nature, unfortunately for the gold-seeker, has distributed the gold mostly in minute particles, the extraction of which from their rocky matrix is a knotty problem. Before the auriferous gangue or ore can be subjected to any further metallurgical process it



Wernher, Beit & Co.

HEADGEAR, VILLAGE DEEP MINE.



MODEL OF STAMP BATTERY.

CLOSED

must undergo some sort of mechanical treatment, more especially crushing and grading.

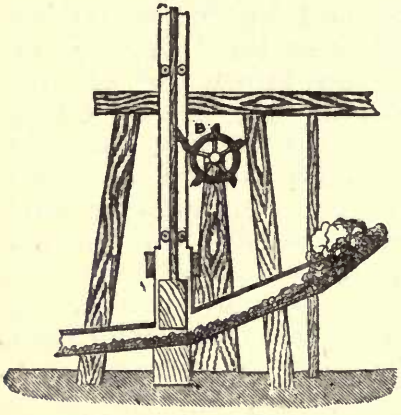
Among the earliest contributions to the history of the metallurgy of gold is that of Pliny, who tells us that in his time mercury was used as a medium for separating the precious metals. Vitruvius also gives a detailed account of the process of recovering gold by amalgamation from the cloth into which it had been woven.

Quicksilver is still largely used for the extraction of free or pure metallic gold from the "brown" or "free-milling" ores. From this brown ore the refractory or "rebellious" elements have been oxidized or eliminated by natural processes, leaving the gold free and clean. It is then readily capable of amalgamation with mercury. It is an interesting fact that these brown ores are usually found in that portion of a vein lying above the level of the perpetual water-line. Below this level the gold generally occurs, not in the metallic form, but in some chemical combination such as the sulphides, which are not amenable to amalgamation, but, as we shall see, require special treatment.

The first step towards the separation of gold from the ore is to crush the latter as finely as possible by means of rock-breakers and stamp batteries. The stamp-mill was first used for the crushing of ore in Roman times, but was first applied to the treatment of gold ore in California, and its use has since spread all over the world, wherever gold is found. In mills of the Californian type the stamp or crusher is a cylindrical iron pestle with a detachable iron face or shoe—which can be replaced when worn out—attached to an iron rod or lifter. The average weight of these huge pestles is from 600 to 900 lb., but stamps weighing 1,320 lb. are in use on the Rand. The lift is effected

by cams acting on the under surface of tappets or cylindrical boxes keyed on to the lifter about three-fourths of the way up.

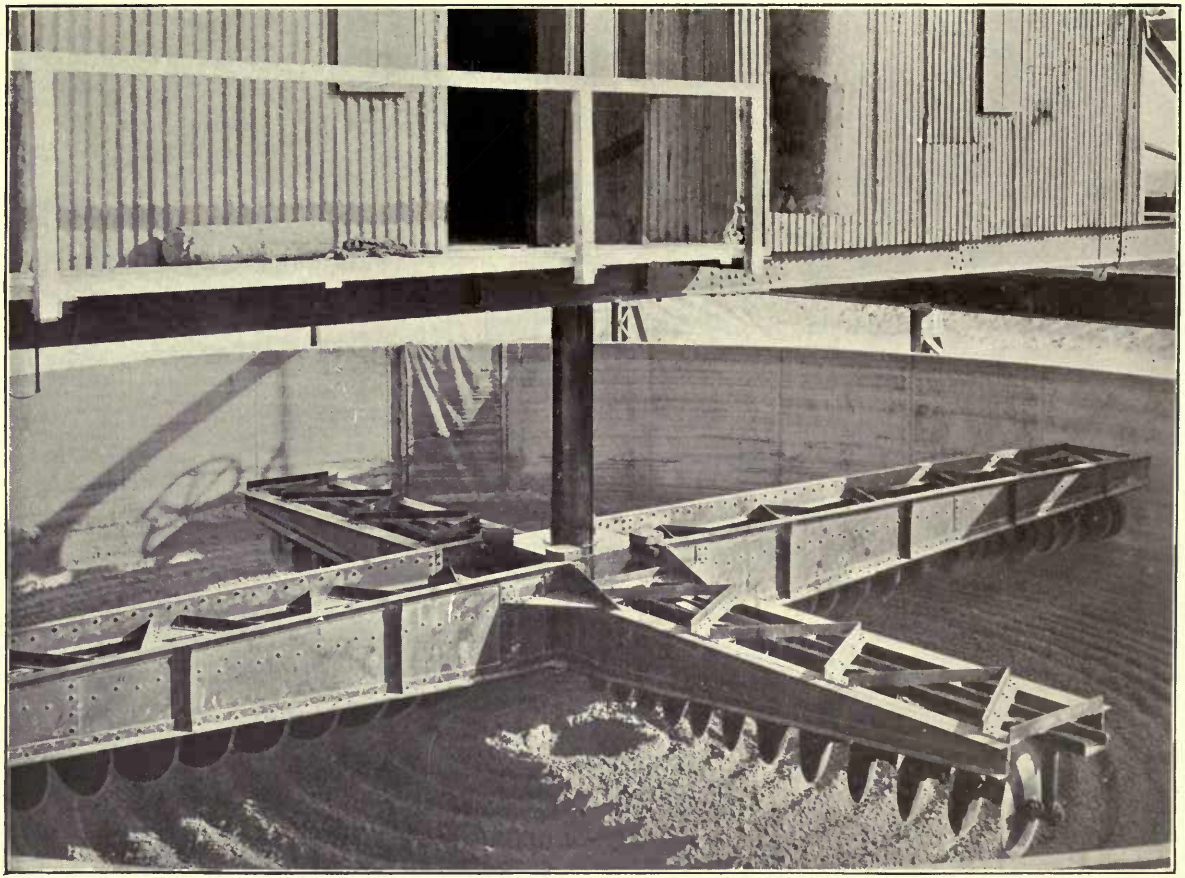
As, however, the cams, unlike those of the old Cornish or European type, are placed to one side of the stamp, the latter is not only lifted but turned partly round on its own axis, and the shoes are consequently worn down more uniformly. The height of the lift may be anything from 4 to 18 inches, and the speed of working from 30 to 100 blows per minute. As may be imagined, the noise in a mill employing perhaps as many as 240 of these ponderous ore-crushers, is deafening, and one of the first things which strikes a visitor to the Rand or any other quartz-mining district of to-day is the incessant roar of the numerous stamp-batteries.*



OLD CORNISH STAMP.

The ore is fed in through an aperture at the back of the "battery-box" or trough in which the stamps work. A regular supply of water is admitted from above, and mercury in a finely divided state is also added. The water, with the crushed rock in suspension, forms a muddy mixture called the "slime," which is splashed through slits and flows forward over an apron or table in front covered with amalgamated copper plates. These tables are laid at an angle of about 8°, and are about 13 feet long.

* See a passage in Martial on the noise caused by the operation of the stamp mills erected in Rome to crush the ore from the mines. *Vide* Del Mar.



Wernher, Beit & Co.

AGITATING GEAR, ROBINSON GOLD-MINE.

With the plates they are generally supposed to collect from 10 to 15 per cent. of the available gold. In some mines the slimes are then allowed to pass over blankets, the woolly hairs of which, like the golden fleece of old, retain the fine particles of gold. In the old Californian mills, the slimes, after passing the blankets, and also those from the special amalgamators, were discharged into the Eureka rubber. This was a contrivance by means of which any particles of gold which had hitherto escaped amalgamation were cleaned and brightened by rubbing, and were then collected on quicksilvered plates. The method more favoured nowadays is, however, to lead the sands or slimes through a gutter about 16 inches broad and 120 feet long, also lined with amalgamated copper plates, the particles of rebellious ore having been previously deposited in catch-pits.

When the ore does not contain any considerable proportion of free gold, the mercury is not, as a rule, used during the crushing, but the amalgamation is carried out as a separate process, which is almost invariably based on the principle of the Hungarian or "quick" mill. This consists of a cast-iron pan with a shallow cylindrical bottom containing mercury, and in which a closely fitting wooden muller, armed with several projecting blades, revolves. The stuff from the stamps is conveyed to the middle of the muller. The heavier gold sinks to the bottom and the lighter portion of the slimes is propelled by centrifugal action to the edge of the pan, where it is discharged.

The layer of gold amalgam is removed from the copper plates by a process technically known as "sweating." To separate the gold from the quicksilver the amalgam is first pressed in wetted canvas or buck-skin in order to expel the excess mercury. The lumps of solid amalgam are placed in an iron vessel

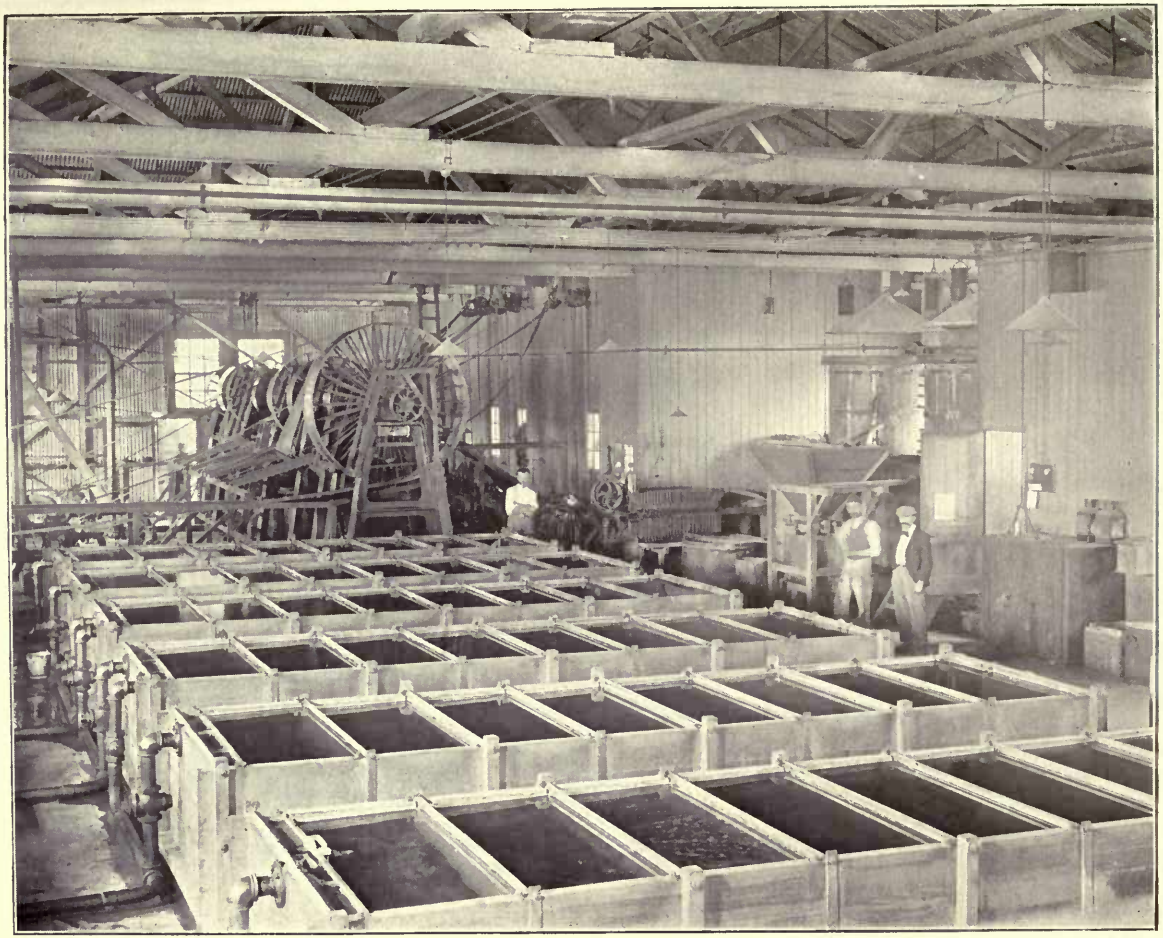
provided with an iron tube leading into a condenser containing water. The vessel is then heated to a dull redness and the mercury volatilizes. The amalgam generally yields from 30 to 40 per cent. of gold. In the larger mills horizontal cylindrical retorts holding from 200 to 1,200 lb. of amalgam are used, pot retorts being employed in the smaller concerns. The bullion left in the retort is finally smelted in plumbago or graphite crucibles, with the addition of a suitable flux.

As I have endeavoured to show, the treatment of free-milling ore by amalgamating the free gold with mercury is a comparatively simple process. To deal successfully with low-grade or rebellious ores, in which the gold is not free or in its metallic state, but in chemical combination, necessitates the employment of more scientific and complex methods. The first consideration in the economical treatment of gold ores is, as we have seen, the complete removal from the low-grade ore of the greater part of the gangue or waste rock. This branch of metallurgy is called concentration or ore-dressing.

The other indispensable preliminaries to successful concentration are exactness of sizing and of classification. Sizing consists in passing the grains of ore through a sieve or *trommel,* which gives a body of grains of equal volume but different densities. These grains are concentrated in jiggers, which complete the coarse concentration.

The jigger is a horizontal hutch of wood or iron divided into two or more sections by a vertical partition or screen. On one side of this are pistons or plungers, which cause a regular pulsation of water through the screen and a classifying of the ore.

Classification comprises the subjecting of the ore grains to the action of a current of water. It is carried

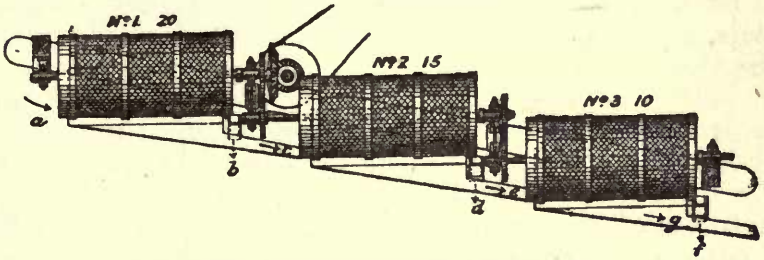


Wernher, Beit & Co.

82] EXTRACTOR HOUSE, CROWN DEEP MINE.

UNIV OF
CALIFORNIA

out in hydraulic classifiers—pointed V-shaped boxes called *spitzlutten* or *spitzkasten*. The resultant product is a mass of grains of ore which differ from one another in volume and density, but fall in a current of water with equal velocity. The separation is effected by subjecting the grains to a washing current of water in a buddle or a vanner which washes away the larger grains of rock and leaves the smaller grains of gold behind. Thus we see that this fine concentration can be carried out by means of either buddles or vanners.



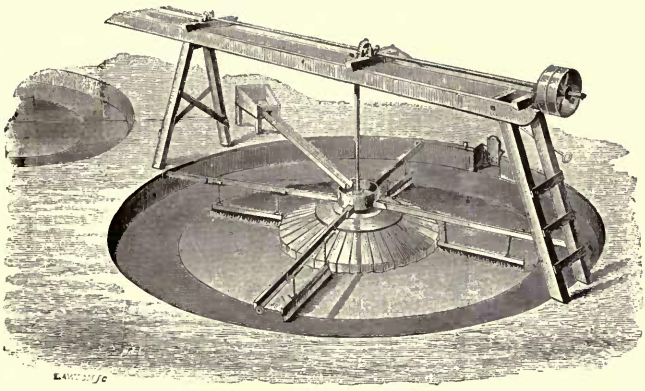
REVOLVING SCREENS, OR TROMMELS.

The buddle is an ingenious machine for the concentration of slimes. The round buddle illustrated in our plate was, probably owing to the simplicity of its construction, for a long time a great favourite with mine managers. This contrivance consists of a shallow circular pit formed in the ground, and measuring from 14 to 22 feet in diameter and from a foot to 18 inches deep. The sides are usually built of stone or brick, and the floor, which is convex, sloping downwards from the centre, is generally of cement. The centre head, which is a fixture, is from 6 to 10 feet in diameter. A revolving head is fixed to the upright central shaft and carries four arms. The revolving head receives the slimes from the trough or conveyor, and distributes

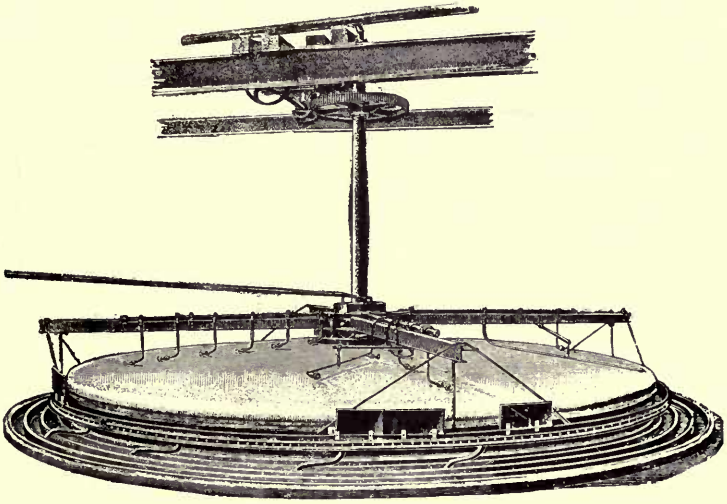
them in an even layer over the fixed head. The liquid stream flows over the edge of the central head and distributes itself outwards over the sloping floor towards the outer edge, depositing the gold and ore it contains according to its specific gravity—the richest and heaviest first and the poorest last and nearest the circumference. To each of the four revolving arms cloths or brushes are attached, which sweep round and smooth out each successive layer of mineral as it is deposited. The great drawback in the use of the ordinary buddle was the fact that the mineral had to be handled several times, thus increasing working costs, and that the machine had to lie idle while being emptied.

Many improvements on the buddle have been devised, and one of the best is undoubtedly the modern Linkenbach table. Instead of having a pit as in the buddle, there is a raised platform or table from 20 to 26 feet in diameter, which is built of masonry with a convex surface of cement sloping downwards from the centre. Rising from the centre of the table is a rotating hollow shaft carrying four arms like those of the buddle. To these arms are attached refining and smoothing water-sprays, and also an annular revolving trough with discharge pipes. This trough revolves below the level of the edge of the table. The slimes are conveyed from the *spitzkasten* to the upper receiving trough, whence they flow on to the table. The action of the Linkenbach table is continuous and automatic. The different products are swept off the table by the revolving arms, and are received by the series of annular troughs fixed round the table for their reception. Thence pipes convey them to the settling tanks.

Numerous types of bump or percussion tables have been invented to supersede the buddle in concentrating the ore, but it is unnecessary to trace here the various



ROUND BUDDLE.



LINKENBACH TABLE.

UNIV. OF
CALIFORNIA

stages of the evolution of the modern form of bump table with a travelling belt, known as the Frue vanner. Of American origin, this machine has been found most efficient in the concentration of pulp and slimes. The Frue vanner consists of a bench and rollers supporting an endless inclined rubber belt, with side flanges. The upper surface of the belt forms an inclined plane some 12 feet long by 4 feet wide. In addition to the ordinary motion of the belt, it receives a lateral or shaking motion. The slime travels down the slope, and the shaking deposits the gold. The belt, however, moves in the opposite direction and carries the ore upwards. Water-jets decide the issue, washing back the lighter sand, and only the heavier gold and mineral passes over the roller and is deposited in the tank below.

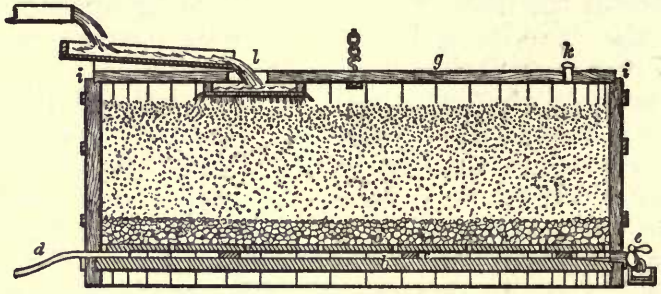
The concentrates or concentrated ores are dried and are then ready for the process of calcination or roasting, a necessary preliminary to the extraction of the gold by the chlorination process. A complete, "dead," or, as the Australians call it, a "sweet" roast, converts all the metals, sulphides, etc. (except gold and silver), into oxides. For this purpose the ores are placed in a specially designed reverberatory furnace which is already heated. Salt is added to convert the lime and lead present into chlorides. Any sulphur in the ore is driven off, and assists in the operation of roasting. The mineral must be continually stirred so as to expose it to the oxidizing action of the air, the supply of which has to be carefully regulated. To secure the necessary stirring or motion of the ore in the furnace, which was formerly done by hand, many ingenious mechanical devices have been introduced.

The auriferous concentrates having been completely oxidized by roasting, it remains to convert the ore by the process known as chlorination into a soluble chloride, then to wash it out from the ore, and finally

to precipitate the gold in its metallic form, ready for smelting.

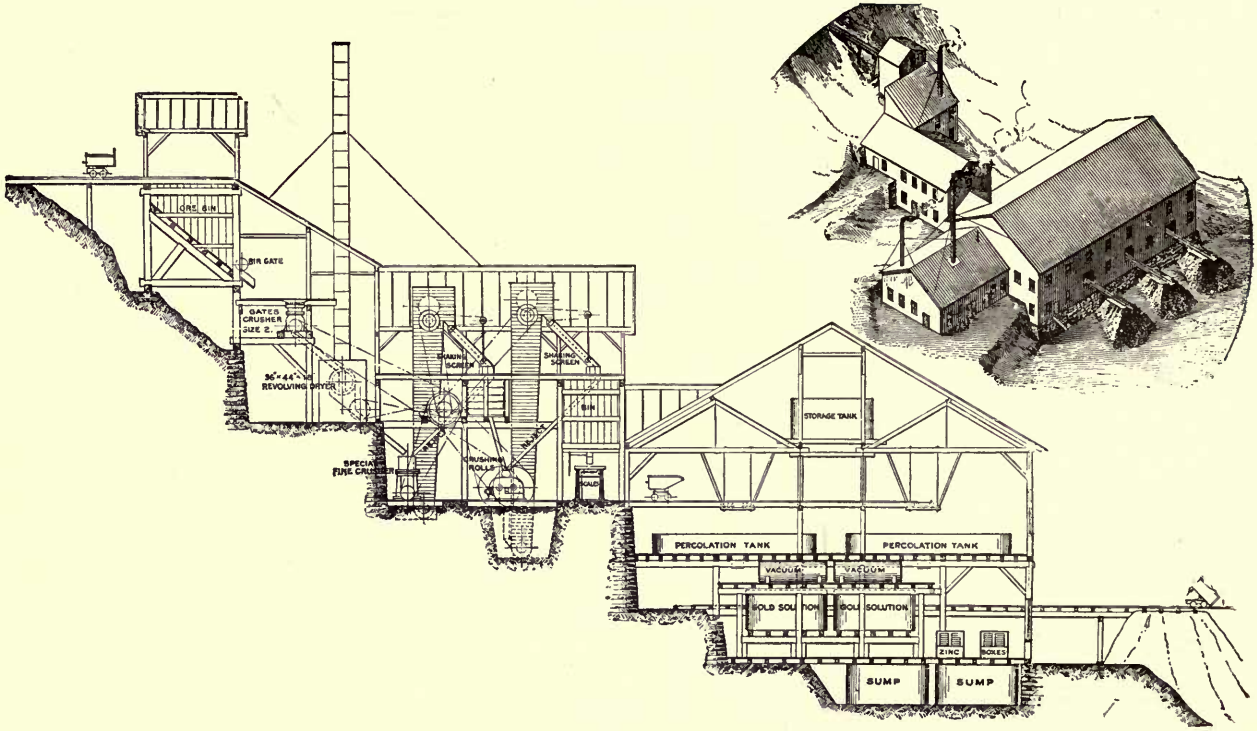
Of the many variations of the process for the extraction of gold by means of chlorination, the first and probably the best known is the Plattner process, which was introduced by C. F. Plattner in 1848. The Plattner process was first used in America by Mr. Deetken at Grass Valley, California, in the " sixties " of last century.

The rationale of the chlorination process may be outlined in brief and general terms. The concentrated milled ore, having been perfectly oxidized, moistened, and sifted, is placed in a vat some 8 or 10 feet square,



CHLORINATION VAT.

made of stoneware or pitched planks, having a perforated false bottom and a close-fitting cover. Both fixed and revolving vats are used. Chlorine gas is either generated from chemicals in the vat itself or it is led from a generator into the vat beneath the false bottom. The gas percolates through the moistened ore, and the vat is allowed to remain closed for from fifteen to forty-eight hours. At the end of that time the gold present in the oxidized ore is found to have changed to a soluble chloride, which is separated by washing the vats out with water repeatedly until no further trace of the gold chloride remains. The resultant liquor is led to settling tanks, where it remains for from twelve to



CYANIDE PLANT: VIEW AND ELEVATION.

UNIV. OF
CALIFORNIA

seventy-two hours. The solution is then drawn off, a precipitant—usually sulphate of iron or charcoal—is added, the gold is deposited as a black or brownish precipitate, and is finally filtered through sawdust or sand. The precipitate is collected, washed, and melted into ingots of nearly pure gold.

The method which is so well known as the cyanide process for the extraction of gold from its ores, was known to Scheele as early as 1782, and also to Professor Faraday, but was not practically applied on a large scale until more recent years. The foremost of the modern variations of the process was that patented by Messrs. Macarthur & Forrest in 1890. The Macarthur-Forrest process came to be very largely employed by most of the leading mines all over the world, and particularly on the South African Rand. It was utilized for extracting gold in a very fine state of division either from the gangue direct, or from the tailings after treatment by the amalgamation process. The cyanide process derives its name from the use of solutions of cyanide of potassium.

The finely ground ore is placed in tanks or leaching vats, which are nowadays mostly of steel, coated with pitch inside and out, and of a capacity up to 1,000 tons. An alkaline solution or caustic wash is passed through the ore as a preliminary. This removes any organic matter, and effects a saving in the consumption of cyanide. Then a strong (0·3 to 0·5 per cent.) solution of cyanide is run into the vat, where it is allowed to remain for several hours. The solution is run off, and the saturated ore is left to drain for some four hours. During this time the solution is still doing its work in dissolving out the gold in the ore, which it does even more readily in the presence of the oxygen of the air. The object of the third operation is to wash out the dissolved gold by means of a weak solution of the

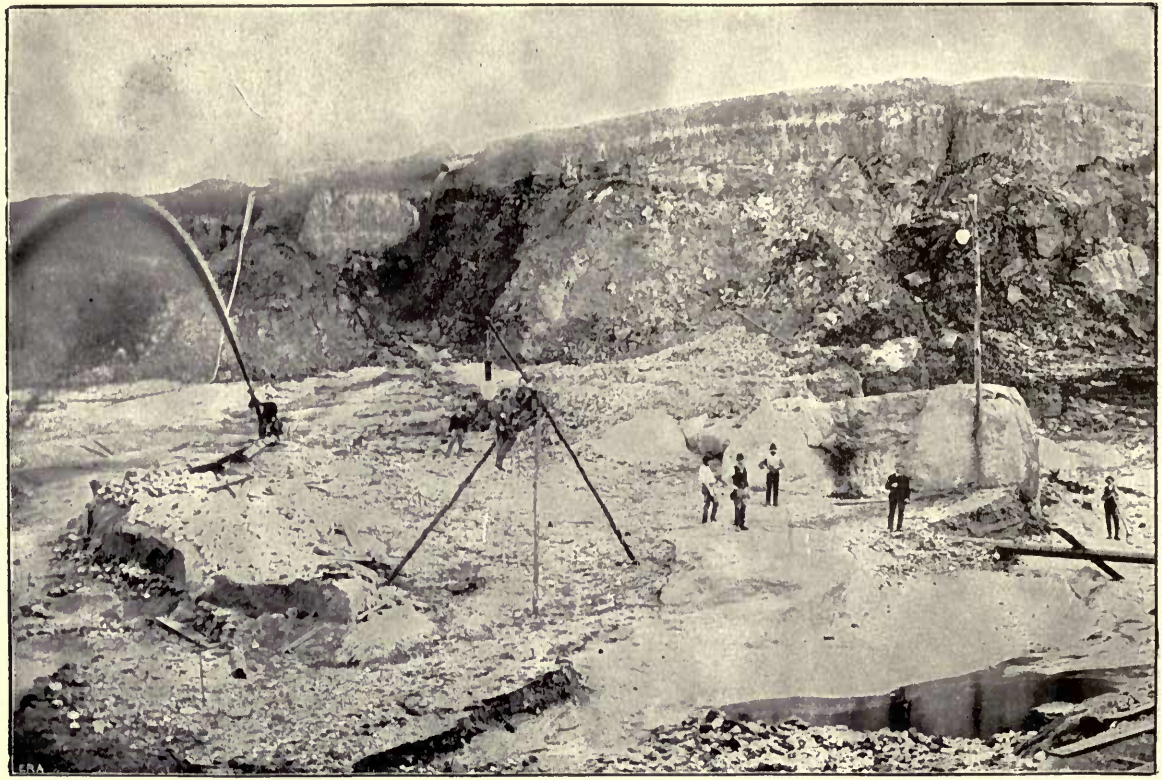
cyanide of potassium. Finally, after the weak solution a water-wash is applied.

The cyanide solutions containing gold are, in the Macarthur-Forrest process, passed through precipitation boxes containing zinc shavings on which the gold is deposited. After settling, the liquor is pumped off, the gold zinc slimes are dried, roasted to oxidize the zinc, and finally smelted in graphite crucibles. In these closing stages of recovering the gold—known as "the clean-up"—it has been found that the cyanide solution is injurious to white men, but the Kaffirs put their hands and arms into it with impunity.

Electricity is now very generally applied to secure the precipitation of the gold from the cyanide solution. The electrolytic process was originated in 1887 by Dr. Siemens, the eminent electrician of Berlin. It was first utilized in the Siemens-Halske process on a large scale in 1894 at the Worcester Mine in the Transvaal. In this process the gold is deposited by the action of the electric current on thin sheets of lead. The advantages of electrolytic precipitation over the employment of chemical precipitants are that the gold is purer and more easily smelted, and that weaker cyanide solutions can be used, thus effecting a saving in chemicals. At the Worcester Mine huge leaching vats were used, 20 feet in diameter. The precipitation plant consisted of tanks 20 feet long by 8 feet wide and 4 feet deep, in which sheets of iron and lead form the electrodes. The gold was deposited on the lead sheets as a bright yellow film. The lead, which contains from 2 to 12 per cent. of gold, was then smelted and cupelled. The actual extraction of pure gold by this process often averages 70 per cent.

"Hydraulicking"

"Hydraulicking," or hydraulic gold-mining, is an interesting and distinctive phase of the industry. Its



HYDRAULICKING AURIFEROUS GRAVEL INTO SUMP.

UNIV. OF
CALIFORNIA

picturesqueness, the magnitude of the operations involved, and the ingenuity with which natural forces are applied concentrated and accelerated, all combine to arrest the attention and impress the imagination.

Hydraulic mining entails the removal of large masses of auriferous gravelly soil by the impact of water under very high pressure, and its treatment *en route*. In California, Australia, and other parts of the world there are large deposits of this gravel containing gold, but not in sufficient quantities to repay treatment, except on a large scale.

By hydraulic mining the whole depth of the deposit or bank of gravel, down to the bed-rock, is washed away by means of powerful jets of water. Such a process requires a large volume of water, which has to be brought in canals or aqueducts from streams or reservoirs high up in the mountains. The construction of these " ditches " or conduits involves the expenditure of a large amount of capital and labour, as some of them are brought over hill and dale from 40 to 100 miles. The water is conveyed from the ditch or canal to the mining claim by means of iron pipes, the supply being from 200 to 500 feet above the point of discharge. These pipes are from 12 to 20 inches in diameter, and are of great strength. They are connected by means of a universal joint with a nozzle. From this nozzle the stream is directed against the face of the gravel bank to be treated. At a pressure of from 100 to 200 lb. per square inch, the curving, glittering jet of water resembles a metal rod and can hardly be deflected with a crowbar. Under the incessant action of this tremendous mechanical force, aided by the softening influence of the water, large masses of the gravel bank come crashing down.

The next point to be considered in " hydraulicking " is the disposal and treatment of the vast quantities of

debris. At an early stage of the industry it was realized that the problem could only be solved satisfactorily if the auriferous gravel could be carried away and discharged into some swiftly flowing stream. To secure this a hydraulic mine has to be provided with a tunnel or open cut, which connects the centre of the gravel bank with the nearest and most suitable creek or river. The upper end of the tunnel, which may be from a few hundred feet to a mile in length, begins on the deepest part of the bed-rock beneath the gravel bed, to which a shaft or incline is sunk from the surface. The tunnel is usually some 6 feet or more in width and 7 feet in height, and has a gradient of from 1 in 24 to 1 in 36. Outlet, dump, and fall have to be provided for the many million cubic yards of gravel displaced, and many mines have had to suspend operations owing to the impossibility of disposing of the accumulated debris which had banked up at the outlet of the sluice or flume.

When the tunnel has been completed, and it is connected with a preliminary shaft or cutting in the gravel deposit, the cut or tunnel is converted into a sluice, sluice-boxes being laid throughout its whole length to direct the stream and retain the gold. For this purpose a trough is constructed of stout planks. The pavement is as a rule composed of wood blocks, alternating with sections of stone paving. Quicksilver is placed in the interstices of the pavement, as much as two tons of the metal being required to charge a long sluice.

The debris of the gravel bank, which speedily crumbles under the resistless force of the water-jets, is swept forward in the sluices, precipitated with the whole volume of now turbid water down the shafts or dumps prepared for the purpose, and then taken up again by the sluices. There it is brought into contact with the quicksilver, and is thus made to give up its gold. Even boulders are shot forward by the im-

petuous stream, and help to crush those harder masses of gravel which have not thus far been disintegrated. Sometimes the lower stratum of gravel is so strongly cemented together that it resists the stream of water until it is loosened by means of explosives. For this purpose an adit or tunnel is driven in on the bed-rock under the gravel, and another at right angles to the first. In these tunnels a large quantity of some explosive, usually from 100 to 1,000 kegs of gunpowder, is placed, and is fired instantaneously by electricity. These vast operations are called by gold-miners " bank-blasting."

The sluices of a hydraulic mine are often duplicated, so that one of them can be cleaned up while work is proceeding with the other. The process of " cleaning-up " is performed at intervals of from fifteen to thirty days, according to the extent of the workings and the nature of the gravel. The pavement and blocks are taken up from the bed of the sluice in order both to collect the amalgam of gold and the " pay-dirt " and also to effect the necessary repairs, the wear-and-tear and eroding power of the tremendous avalanche of watery debris being so great as to necessitate a complete renewal of the pavement in from eight to twelve weeks.

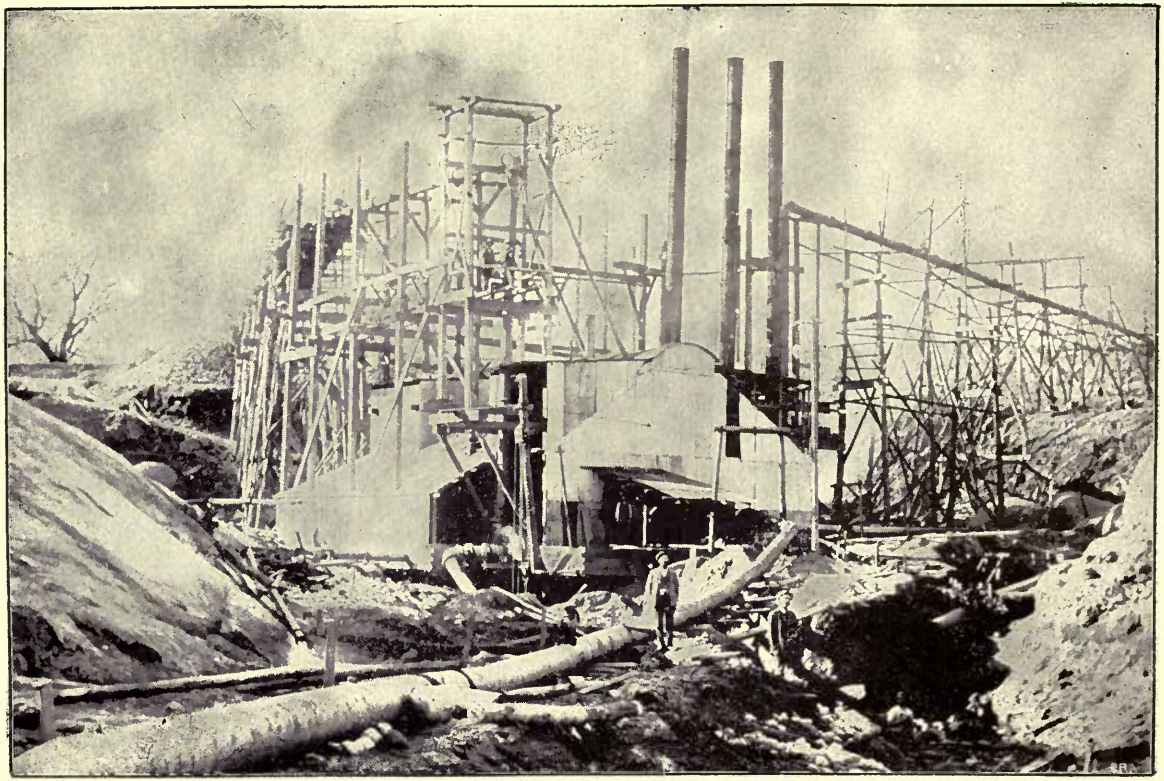
Rude and primitive as this method of gold extraction may seem, experience has proved that it is more efficient than any other yet devised, while it is by far the most economical. It would in fact be practically impossible to treat such vast bodies of material on any other known principle.

In the " seventies " hydraulic mining was carried on in California on a gigantic scale. So great was the amount of debris washed down from the hydraulic mines that between the years 1870 and 1879 the bed of the Bear River was raised in places in its lower course

97 feet, and that of Sleepy Hollow Creek 136 feet. The average filling up of streams in this vicinity was from 100 to 250 feet, and many thousands of acres of fine farm-land were buried under gravel—some 16,000 acres on the Lower Yuba alone. Of course the farmers and landowners indignantly protested, but for many years mining interests were supreme and agriculture was worsted in the struggle. But at length, in 1884, the long and bitter "anti-slickins" or anti-debris fight ended in favour of the farmers. In 1893 a California Debris Commission was established, which, acting in unison with the State authorities, only grants permits for hydraulic mining when all gravel is satisfactorily disposed of and no harm is done to the streams.

The latest and most ingenious method of disposing of the tailings, if a sufficient head of water is available, is to stack them in banks by the aid of hydraulic elevators. This, however, adds to the cost of working, and is only employed when there is difficulty in dumping or disposing of the detritus otherwise.

Gold-bearing gravels have been so frequently found in the beds and bottoms as well as on the banks of rivers and streams, that the use of scoops or dredges was a natural outcome of the desire to work these submerged placers. The idea of dredging river-bottoms for gold was first put into practice in California, but the results were not very satisfactory. Ordinary mud dredges were then employed, but numerous improvements have since been made as a result of practical working and experience, and have resulted in the evolution of the steam gold-dredge of to-day. Dredges of special design are now working in the rivers of the auriferous districts of Australia, California, New Zealand, and other countries, and have on the whole been fairly successful. Dredges are now employed not



BARGE FOR HYDRAULICKING, FULLY EQUIPPED.

only in working the beds of rivers, but also in excavating shallow flats when the ground is not over 40 feet in depth. The banks of streams and lakes can, too, be worked without difficulty if there is a regular water supply.

The modern steam dredge with steel pontoons, used for gold-dredging, is provided with an endless chain of buckets or scoops, resembling those of the dredgers familiar in the estuaries of our great rivers. The gravel raised by the elevator is dumped into a hopper, whence it passes into revolving *trommels* or cylindrical screens, which separate the coarse materials from the fine sand. This latter, which usually contains most of the gold, passes through sluice boxes lined with riffles and the indispensable quicksilvered plates. The coarser gravels fall into an iron shoot and thence into the sluice. The residue and tailings are thrown out at the stern of the dredge, a special elevator conveying them clear of the vessel, and in many cases piling the debris on the bank.

Latterly the dredges on many of the Californian streams have been worked by electricity generated by water-power at a distance. Dredging has come to be an important part of the gold-mining industry in California, more particularly since the year 1900. Thousands of acres of farm, orchard, and even vineyard lands have been treated in the quest for gold by this method.

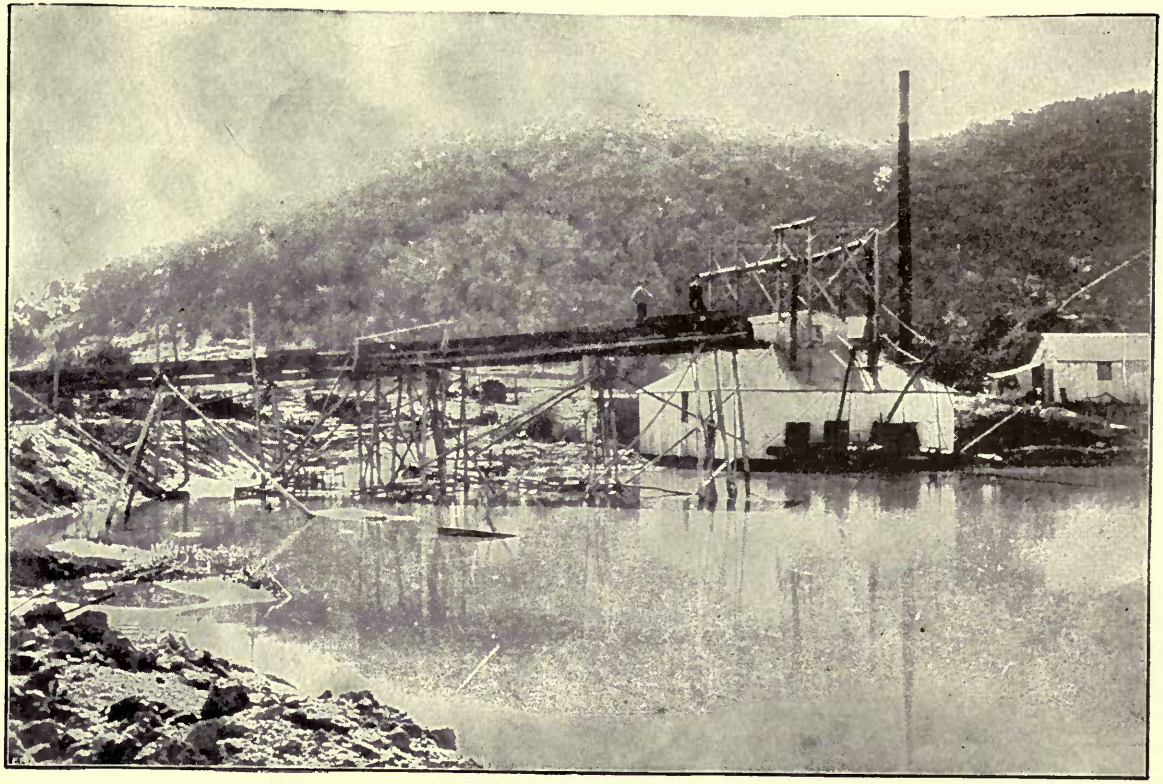
The great advantage of dredging is that it is found to be not only feasible but remunerative where no other mode of working is practicable. The enormous amount of material excavated by a modern dredge, and the relatively low cost of working—manual labour being almost entirely dispensed with—admit of low-grade auriferous gravels being treated with profit.

A novel and ingenious system of mining auriferous

gravels and drifts in flat and low-lying country has of late years come into vogue in Australia, and particularly in Victoria and New South Wales. Large deposits of alluvial gravel often exist, as we know, in the beds of small streams and creeks in auriferous districts. Where there is no fall or grade to facilitate the carrying away and disposal of the tailings, the ordinary type of hydraulic mining cannot be resorted to, and some other method has to be sought.

For the purpose of dealing with gold-bearing deposits lying below the general level of the surrounding country and liable to floods and inundations, an ingenious combination of dredging and "hydraulicking" has been devised. This alluvial gravel-pumping is an amphibious contrivance, consisting primarily of a centrifugal pumping plant placed on a wooden raft or barge capable of floating the whole thing. The barge provides against the risk of sudden flooding, and at the same time provides an easy means of moving the plant from one place to another. These gravel-pumping barges differ from dredges in that the machinery is never at work while the vessel is afloat, but only while it is stationary and resting on the gravel bank. The barge forms simply a portable foundation for the mechanical equipment, which consists primarily of a powerful centrifugal pump specially designed for pumping sand, stones, and gravel; together with the necessary boiler, engines, and appliances for treating the auriferous gravel.

If a bank of such gravel is located in low-lying, watery ground, an excavation is made close by, and, if possible, at a lower level, large enough to float the barge. The barge, which is made of heavy timber, is put together and floated, and the machinery is placed in position. Then the water is pumped out of the excavation and the ground under the barge is



HYDRAULICKING BARGE, READY FOR TOWING.

Digitized by Google

dug away until bed rock is reached. A large sump-hole or well is cut in the rock in which the pump is intended to work. These preliminary operations completed, the barge is ready for use. The gravel bank is generally washed down into the sump in the " hydraulicking " fashion previously described, and if a water supply with sufficient " head " or force is not available, a powerful steam pump on the barge may furnish the necessary hydraulic jet. The gravel is washed down along sluice races cut in the rock to the sump-hole or suction well, where, too, most of the gold finds its way. From the well the mixture of water and solid matter is pumped, sometimes to a height of 70 feet, the sluice boxes being placed on a high scaffolding so as to provide sufficient fall for the tailings. The latter are dumped on waste land, or if the operations are sufficiently advanced, and the barge is floated into a new position, the tailings are used to fill up the old workings. If it is decided to work the bed of a stream by this method the water is either diverted by means of dams and races, or, if the stream be a small one, it can be dealt with by means of an extra pump on the barge.

CHAPTER VI

LATER GOLD BOOMS

ESTERN AUSTRALIA had been frequently prospected for gold, but it was not until the year 1885 that promising traces were found at Kimberley, in the far north of the colony. Shortly afterwards Kimberley was proclaimed as a gold-field, and there was the inevitable rush of gold-seekers. Five years later gold was found at Yilgarn, and afterwards at Pilbarra, Murchison, and several other places. Then in 1892 came the news of the locating of the precious metal by Bayley and Ford in the rich fields at Coolgardie, and there followed the great "Westralian" boom. Even richer deposits were found in June, 1893, by Patrick Hannan, and his mate Flanagan, at Hannan's, afterwards called Kalgoorlie, where one tract at Boulder so teemed with the precious metal that it was called "the Golden Mile." But to the individual or inexperienced gold-digger the West Australian goldfields are disappointing. With one or two minor exceptions there are no alluvial deposits in the colony.

Some gold was procured by the "dry-blowers," who, in the absence of water, blew off the sand from the gold.

The inland gold-fields of Western Australia are for the most part situated on a plateau. Between two barren tracts of granite and gneiss, the first gold-bearing belt extends from Phillips River on the south coast to Southern Cross on the Perth to Kalgoorlie railway, and then on through Mount Magnet, Lake Austin, and the Murchison gold-field at Nannine and across the Peak field to the heads of the Gascoyne and Murchison Rivers. The second auriferous belt lies more easterly, and includes the principal gold-fields of the colony. It extends from the Dundas field in the south, includes the mining centre of Norseman, and embracing Coolgardie and Kalgoorlie's "Golden Mile," stretches away to the Leonora and Pilbarra mining districts.

The surface of the country generally presents a desolate and monotonous appearance—vast, sandy, undulating plains relieved only by occasional patches of scrub and a few gum trees. The railway line from Perth to Coolgardie, which lies some 360 miles inland, runs through the waterless bush. It is a weary journey through a forbidding and depressing wilderness; and the traveller, seeing from time to time the sandy tracks leading past the waterholes to distant mines, wonders whether so many people would have penetrated so far into the heart of this parched and inhospitable land if it had not been for the buried treasure of the gold-fields. An Australian writer has voiced his sense of the nakedness of the land in vivid verse:

> "A fierce sun glared down upon a gaunt land, stricken
> With barrenness and thirst,
> Where nature's pulse with joy of spring would quicken
> No more, a land accurst."

A strange sight, too, one that makes the new-comer

imagine he has strayed into the dreamland of the Arabian Nights, is the spectacle of a long train of camels, which, with tinkling bells, and led by an Afghan driver, bear heavy loads to mines up country. The camel seems to find congenial surroundings in West Australia, and is the only possible beast of burden in this sandy, roadless, waterless country.

Coolgardie is a clean and handsome modern mining town of about 4,000 inhabitants. It is the Governmental headquarters of the West Australian goldfields, and is the residence of most of the mining engineers and mine-managers of the district. Following on the rich but ephemeral early finds at Bayley's Reward and Londonderry, over 150 mines were opened up and companies floated. Most of these mines have, however, since had to close down.

Kalgoorlie, the centre of the richest and most important gold-field in Western Australia, lies 20 miles east of Coolgardie. Within twelve months of the first discovery of gold at Hannan's, as it was then called, several mines were making returns. These proved so profitable that a boom was inaugurated, and Kalgoorlie supplanted Coolgardie, becoming the most important mining centre in West Australia. Kalgoorlie is now a straggling town with a population of over 6,000.

Hannan's Belt, in which formation all the Kalgoorlie mines are situated, extends about seven miles from north to south, and is about a mile and a half wide. In the formation, which also runs north and south, are a number of parallel lodes, carrying gold, though usually in unpayable quantities, throughout their lengths. A section taken across Hannan's Belt would reveal possibly fifty gold-bearing lodes, for the most part non-remunerative, and also the presence of gold in minute quantities in most of the less clearly defined lode matter. As to the nature of this lode matter, it was something

KALGOORLIE MINE: SOUTH DRIVE, 1,050-FOOT LEVEL.

of a novelty in the history of gold-mining—a mixture of talcose schist, diorite, and quartz, heavily mineralized throughout. A considerable quantity of the rare telluride of gold is found mixed with the lode whenever the deeper unoxidized or sulphide level is reached.

The reaction after the boom revealed the fact that there were less than a dozen really good mines in the Kalgoorlie field. Seven of these adjoin one another, and are situated within an area of about one square mile —the " Golden Mile " of Hannan's Belt. There is no known reason why the parallel reefs in this particular section should contain such rich patches of ore, but the fact remains that this square mile is a real " Tom Tiddler's ground," and, as one writer has said, " probably contains more gold than any other area of equal size yet discovered in the world." * The reefs are unusually thick, rarely being less than 6 feet, and sometimes as much as 30, 50, or even 80 feet in thickness, and carrying payable gold throughout the entire width.

The discovery of telluride of gold, particularly in the form in which it occurs in the Kalgoorlie gold-field, was considered by experts to be of the greatest importance in proving the permanence and richness of the gold supply. This form of telluride is a mineral resembling silver in appearance, and is composed of gold, silver, and tellurium in varying quantities, averaging 43 per cent. gold, 2 per cent. silver, and 55 per cent. tellurium.

The yellow metal is found in many uncommon forms among the ores of the Kalgoorlie gold-fields. One of the most peculiar is what is known as " mustard " (or amorphous) gold. If this clay-like mineral is examined under the microscope, it is found to consist of minute particles of gold—rounded globules, all filigreed or con-

* " The Gold Mines of the World," by J. H. Curle (1899), Ch. V. p. 163.

glomerated together. If this spongy mass is pressed with the blade of a knife, although it is very soft and malleable, its metallic lustre becomes at once apparent. This mustard or clay-like gold can be obtained artificially by dissolving a piece of telluride of gold very slowly with sulphuric acid.

"Sponge gold," which resembles mustard gold, but is even more like a sponge in structure and formation, and has a bright yellow metallic lustre, also occurs at Kalgoorlie. In appearance it resembles a piece of the most beautiful gold filigree work. This form of gold has been found in large quantities in the Great Boulder Mine, as much as 70 lb. weight of pure gold having been obtained in one bunch of ore. "Under the microscope this gold presents the appearance of a mass of gold crystals with brilliant facets and gold in filiform and arborescent shapes." *

West Australia's maximum output was in 1903, when 2,064,801 oz., of the value of £8,770,729, were produced. The total yield up to the end of 1909 amounted to over £91,000,000, but since 1903 it has been slowly declining.

That part of Alaska and of British North America drained by the Yukon River has only been explored and opened up within comparatively recent times. In 1840 an agent of the Hudson Bay Company first crossed into the watershed, and seven years later Fort Yukon was established at the confluence of the Porcupine and the Yukon. It was not however until about the year 1878 that prospectors began to explore the country for gold. Their efforts met with some success, several miners entered the Yukon country by the Dyea Pass in 1882, and Alaska first appeared on the list of gold-producing countries four years later. Coarse gold was

* *Vide* Mr. A. G. Holroyd, M.E., in a paper read before the Australian Institute of Mining Engineers at Sydney, April 22, 1897.

located at Forty Mile Creek, American territory, in 1887. In the same year Dr. G. M. Dawson, Director of the Canadian Geological Survey, assisted by Mr. William Ogilvie, explored that part of the North-West Territories drained by the Yukon and reported " that in proximity to the (Alaskan) boundary line there existed extensive and valuable placer gold-mines in which even then as many as three hundred men were at work." The number of men engaged in mining in the Yukon valley increased year by year. The miners followed up the rivers and their tributaries while washing for traces of alluvial gold, and this led finally to the discovery of the rich Klondike gold-fields in 1896.

Then ensued, in 1897–1898, that sensational rush to the Klondike, which recalled to many the early days of the Californian boom. Americans predominated, and French Canadians or *Canayens*—those *voyageurs* of the North-West—were fairly numerous, as also Englishmen, Scotsmen, and Swedes, but comparatively few of the Latin races appeared prepared to face the icy rigours of the Arctic winter.

At first the difficulties of access to the Yukon region were very considerable. The most direct route, and the one most used by the early miners, was from Dyea over the Chilcoot Pass (3,600 feet), and down to Lake Lindeman. There were several variations on the overland route—others being via Skagway or over the White Horse Pass from Seattle—but all were frightfully arduous. The only alternative was, after the break-up of the ice in the spring, the easier but longer and more tedious journey by steamer to St. Michael's at the mouth of the Yukon, and then up the river in the crowded and primitive river steamboats. Still, within four years over 30,000 gold-seekers entered Alaska.

The gold was found in the alluvial gravels forming the bottoms of the valleys of the Klondike or main river

and its tributaries, over an area of about 800 square miles. Nearly all the streams were gold-bearing, the richest and most important being Bonanza Creek, with its famous tributary Eldorado Creek, which for two or three miles was one of the richest placers on record; Bear Creek and Hunker Creek flowing into the Klondike; and Quartz Creek and Dominion Creek, with Gold Run and Sulphur Creek, two tributaries of the latter, flowing into Indian River.

The yellow metal was also located in the terrace gravels, which occur intermittently at a slightly higher level along the sides of the valleys, and in the quartz drift accumulated in masses varying from a few feet to 120 feet in thickness, and in width from 300 feet to half a mile or more, the origin of which is obscure. The stream gravels, which formed a layer from 4 to 10 feet in thickness, rest upon broken and decomposed schists forming the bed-rock, and are overlaid with a bed of dark peaty matter locally termed "muck."

During the short summer, which lasts only some three and a half months, the early placer claims were worked by means of ground-sluicing. This meant diverting the stream out of its course for the full length of the claim, and sluicing the auriferous gravel bed in sections, while the stream had to be redirected into its original course at the lower end of the claim so as not to interfere with the rights of the diggers on the adjoining claims.

A very different method has to be adopted, however, during the long and intensely cold Arctic winter of these high latitudes. The auriferous gravel is frozen into an adamantine mass on which the blows of the pick are of no avail. Dynamite was at first tried, but a heavy shot resulted in blowing out only a pot-hole, and had no effect on the surrounding gravel. But some digger conceived the simply ingenious idea of burning

out prospect holes by fire, and the plan was quickly adopted. The prospector selected a likely-looking spot on his claim and built a big wood fire, which he lighted at night. Next morning he would find it possible to shovel out a foot of dirt. This process was repeated, and when the hole got too deep for shovelling a windlass was erected. The "pay-dirt" was allowed to accumulate until the spring, when it was sluiced in the usual way. A more efficient method of thawing the frozen ground was provided by the introduction of steam. The steam thawers consisted of a small boiler, a length of strong hose, and a pointed steel nozzle. The nozzle was driven into the ground and the steam was turned on for from four to six hours. The ground at the end of that time was softened for some distance, and the "pay-dirt" could be dug out and piled in heaps ready for washing in the spring floods.

The gold deposits of the placers as well as of the accompanying gravel were believed to be of local origin and derived from quartz veins in the district. Prospectors were active in searching for productive veins in the country rock, but strange to say—and the Klondike is almost unique in this respect—no quartz veins of any importance were found. The output, which reached a value of $22,000,000 in 1900, had decreased to about a quarter of that sum in 1906. The miners drifted away to Cape Nome and other places, and the population of Dawson City dwindled from 10,000 to 3,000. The total gold yield of the Canadian Yukon from 1896 to 1903 was, according to the Canadian Geological Survey, $96,000,000.

Additional discoveries of gold brought the total production of Alaska up to a value of £1,400,000 in 1901 and £3,006,500 in 1905, or a grand total in the period from 1880 to 1906 of some £20,000,000. A considerable proportion of the gold output of Alaska is derived from

the extensive low-grade quartz-mines near Juneau. The town of Juneau or Harrisburg, situated at the mouth of Gold Creek in south-east Alaska, owes its prosperity principally to the gold-mines in the neighbourhood. Placer gold was found at the mouth of the creek in 1879 and the " city " was settled in the following year by two prospectors named Joseph Juneau and Richard Harris. The camp was called Harrisburg until it was given its present name of Juneau. The principal gold-mines are situated in the adjacent Silver Bow basin, the source of Gold Creek and the site of the Great Perseverance Mine.

Of the mines on the Treadwell Lode on Douglas Island, two miles from Juneau, the Treadwell Mine is the most important. The Treadwell mill, which began operations in 1885, was at that time the largest in the world, having 120 stamps in all. Although the lode consists of low-grade ore, it is worked at a profit. The motive power being water, the working costs are unusually low. Transport in some of the inland fields is a problem even more serious than the severity of the climate. The Tanana fields, for example, are provisioned from Circle City, 125 miles away, and the freightage is 1 cent per pound per mile, or $2,000 per ton for 100 miles.

Gold is frequently found among the sands of the sea shore, as for instance in the black sands of the New Zealand, California, and Oregon coasts, but seldom in sufficient quantity to make its recovery a remunerative undertaking. Cape Nome, that lonely Arctic peninsula north of the Yukon estuary, was a notable exception. In the summer of 1899 came the magic cry of " gold," and the solitude of the far-off Arctic beach was transformed into a busy mining camp. In the few short summer months the 2,000 workers are said to have taken some $2,500,000 worth of gold from the beach.

The alluvial deposits on the beach occur in a strip

of comparatively fine gravel and sand, 150 yards wide, extending along the shore. The gold is found in stratified layers with ruby and black sand. During the boom it was washed by the gold-seekers in the most primitive fashion, and it was said that a man with a "rocker" made from an ordinary soap-box could take out £5 worth of gold in a day.

The beach rises gradually to a sharply cut bench which lies 100 or 200 yards from the surf. From the edge of this terrace, which is about 20 feet high, a swampy, moss-covered *tundra* or coastal plain extends inland, rising only some 200 feet in 4 or 5 miles. Further exploration of the interior will probably result in the location of additional auriferous deposits in this most inhospitable and forbidding region.

Thus far I have essayed to put into words the story of human endeavour scarred on the surface of old mother earth through the centuries by her sons in search of gold. From Arabia to Peru, and from Tasmania to Cape Nome in icy Alaska, we may find traces of this unending quest. No obstacles of distance or inaccessibility, heat or cold, danger or pestilence, are sufficient to deter the eager Argonaut. History repeats itself in gold-mining as in other phases of men's affairs. There is the romantic discovery, the headlong rush to the diggings, the excitement, the lawlessness, the social and economic unrest. These are simply the expression and outcome of cupidity and the desire to "get rich quick." The capitalist now follows close at the heels of the digger, with all the resources of science and organized industry at his command, and it may be thought that the palmy days of the lone miner are over, and with them all that is romantic in the story of the gold-mines. But, as has been said, the tale is unfinished, and until all the unknown places

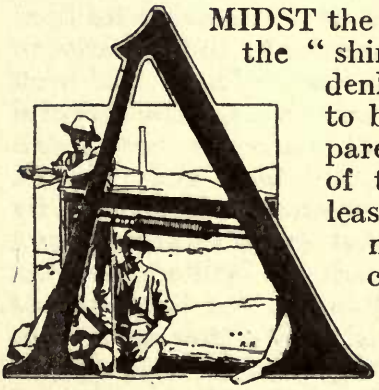
of the earth are explored and prospected, must so remain. Some may think the story a sombre one, but at least it has the saving grace of being true. The words of R. W. Service, the Canadian poet, make a fitting epilogue to the story of the mines of gold:

"Little of joy or mirth,
Little of ease I sing;
Sagas of men of earth,
Humanly suffering,
Such as you all have done;
Savagely faring forth,
Sons of the midnight sun,
Argonauts of the North."

DIAMONDS

CHAPTER VII

GEMS OF LONG AGO



AMIDST the transience of things beautiful, the "shining gloss that vadeth suddenly," the precious stones seem to be in a class apart; and, compared with the general mutability of things earthly, they are the least mutable and among the most beautiful. Brightness and colour appeal to the most untutored mind, but when brightness becomes brilliance, and to colour is added hardness and imperishability, as in precious stones, it is no marvel that these rare gems have been desired and cherished since they were first known to man. Of all precious stones the diamond has long been considered the purest, the most brilliant, and the most valuable. Its radiant purity reveals a heart of fire. Within its colourless, translucent depths blaze all the colours in nature. Transmuting and transforming light, it seems to imprison its rays until it becomes itself a well of light and a blaze of brilliance. What more fitting or

more perfect emblem for the diadem of princes, or more lovely adornment for the *grande dame*, than the diamond? This purest and brightest of precious stones is indeed "a thing of beauty and a joy for ever."

The rough diamond as found in nature is by no means so brilliant as the cut and polished gem more or less familiar to our modern eyes. It is intensely hard and of luminous appearance, but the "nyf" or outer skin is like a dull film over an interior radiance. Despite the absence of external lustre, however, there is an inner fire that differentiates it from all other stones.

Modern science can tell us but little of the origin of the diamond; there is even doubt as to its true matrix. Scientists assert that it is pure crystallized carbon, differing little in composition, but greatly in appearance, from graphite or coal. There has been keen and prolonged controversy as to the natural source of the diamond. Small diamonds have been found in meteorites, and the fact that M. H. Moissan has produced the diamond artificially by allowing carbon to crystallize at an intense heat and pressure in molten iron, has led Sir William Crookes and others to infer that the diamond has been formed in molten iron of volcanic origin. Further than this, scientists have discovered a great deal about the nature of the diamond. We know that it is unaffected by acids and is infusible, but on the other hand we learn that it burns in oxygen at the almost inconceivable temperature of 4,000° F. and leaves no residue.

A precious stone corresponding to the diamond has been known from the earliest antiquity. Its Greek name, *adamas*, meant invincible, or, more literally, untameable, but whether it was always applied to the gem we know as the diamond is uncertain. Hindu legend in the "Mahabharata" tells of a diamond worn by one of the heroes of five thousand years ago.

GEMS OF LONG AGO

Some of the ancients ascribed the most wonderful and magic qualities to diamonds and other precious stones—a sort of spiritual as well as a material potency. They believed in their efficacy as talismans and charms, and credited them with the power of curing diseases, averting calamities, and exorcising demons. This tendency of primitive man to ascribe the inexplicable to the supernatural is a natural instinct; and as we know, the origin of the diamond is a mystery even to the modern scientist. The custom of endowing precious stones with magical and talismanic virtues persisted for very many centuries—until the time of the alchemists in fact, and even later in some countries.

That diamonds, among other precious stones, figured largely in the popular imagination and estimation is evident from the frequent references, both literal and metaphorical, to be found in the Scriptures and other ancient writings. The most remarkable allusion occurs in Exodus in the description of the breastplate of Aaron, which was adorned with symbolic gems, each inscribed with the name of one of the tribes of Israel. The *Yahalom* or diamond was supposed to represent the tribe of Zebulun. But methods of engraving the true diamond can hardly have been known to the Hebrews at that period. In those early days it is possible that the diamond was sought more for its hardness, and its usefulness in engraving other stones, than for its brilliance. Indications of this are also to be found in the Old Testament. The " Shamir " of Ezekiel and Zechariah is translated in the English version, after the Greek, to " adamant " and " adamant stone," but in Jeremiah is translated " diamond." The prophet says " The sin of Judah is written with a pen of iron, and with the point of a diamond " (Jer. xvii. 1).

According to Mr. C. W. King, in his " Natural

History of Precious Stones," the first undoubted application of the name *adamas* is found in Manilius (A.D. 16). But Plato (429–347 B.C.) described the diamond, which he distinguished from other precious stones as being a kind of kernel formed in gold.

As Rome superseded Greece as a world-power the Greek name for diamonds, *adamas*, became Latinized as *diamas*. The extreme hardness of the diamond appealed strongly to the Roman imagination, but was greatly exaggerated even by such writers as Pliny and Lucretius. The former, who referred to the diamond as " the most valuable of gems, known only to kings," also wrote : " The test of these diamonds is made upon an anvil by blows of the hammer, and their repulsion for iron is such that they make the hammer fly in pieces, and sometimes the anvil is broken." The first diamonds known to the Romans were brought from Ethiopia, but Indian stones must have reached Rome before the beginning of the Christian era, as Pliny, in describing the varieties of diamonds, mentions those hailing from India. We know that these were mined in India at a very early date, and later Roman writers mention several rivers of the Far East in the sands of which diamonds were found. India in fact soon began to furnish the whole world's supply, and continued to do so for many centuries.

With the fall of Roman power and civilization the gems and precious stones of its wealthy and luxurious citizens were scattered far and wide, and diamonds shared the common fate of articles of value lost in the gloom of the dark ages. There was no systematic searching for precious stones. The world's stock was increased little, if any: the jewels merely changed owners in successive lootings. In fact diamonds or other precious stones are hardly mentioned in the scanty annals of those turbulent times.

It is in the writings of the learned Arabs, Gerbert and Avicenna, several hundred years later, that we next find any reference to precious stones, some of the theories of Avicenna anticipating by eight centuries the results of modern scientific research. Two centuries further on Albertus Magnus, that remarkable figure of the Middle Ages, gave to the world his great treatise *De Rebus Metallicis*, in which he discusses precious stones and indicates methods of obtaining artificial gems.

The Latin name for the diamond (*diamas*) had been established, with slight variations, by mediæval writers in the vernacular of the different nations of Europe. The word is, however, apparently older than actual acquaintance with the stone itself, as the diamond was little known in Western Europe until the fourteenth century. When it became known to some extent, the credulousness of ignorance attributed to it various occult powers bordering on the miraculous. It was credited with the faculty of averting insanity, and of rendering poison harmless to its owner; it was known—and this in one sense appears more reasonable—as the *pietra della reconciliazione*, or as a peacemaker between husband and wife. Even so late as the sixteenth century Jerome Cardan, author of *De Subtilitate*, solemnly assured his readers of the many virtues possessed by precious stones.

On the other hand, probably owing to the practical difficulties in the way of cutting and polishing the diamond, it was not considered at one time to be equal in value to the ruby or the emerald. In the middle of the sixteenth century so clever a lapidary as the inimitable Benvenuto Cellini ranked it only third among precious stones, placing the ruby first and the emerald second.

The demand for diamonds and other precious

gems was by this time fairly large and regular, and the chief supply was derived from the East Indies. The greater proportion was procured from India, but later they were also brought from Landak and other places in Borneo. Most of the Indian princes claimed all the larger stones found in their territory, and it is said that the Sultan Mahmoud (A.D. 1177–1206) left in his treasury more than 400 lb. weight of diamonds.

Diamonds have been found in many different localities in India, but by far the most productive diamantiferous area was a tract on the eastern side of the Deccan, round the ancient fortified town of Golconda. The precious stones were found in the ancient sandstones and conglomerates, and in the river gravels and sands derived from them. The diamond-bearing beds were for the most part well defined, though frequently not more than a foot thick, and contained pebbles of quartzite and jasper.

The principal diamond-mining districts of the past, in India, have been round about Cuddapah, Chennur, Bellary, Kurnul, and Kollur, all near the River Kistna ; Sambalpur, on the Mahanadi, in the Central Provinces ; and Panna, near Allahabad. The mining was carried on by low-caste natives and by primitive methods, as described by the travellers Van Linschoten and Tavernier in the sixteenth and seventeenth centuries. The Dutch traveller Van Linschoten, writing in 1596 of the mines in the kingdom of Bisnager, the capital of which was Hampi in the Bellary district, said : "The diamonds are digged from several hills near the town of Bisnager." The king farmed out mining concessions with the condition that all diamonds weighing above 25 *mangelyn* (between 34 and 35 carats) should be his. The miners were closely watched, and, in the words of Van Linschoten, "if anie man bee found that hideth anie such, he looseth both life and goodes."

Jean Baptiste Tavernier (1605–1689), who was a French dealer in precious stones, visited many of the Indian diamond mines which were being worked during the years between 1638 and 1665. According to his description of the mining of those days, shallow pits were sunk and the gravel excavated was gathered into a walled enclosure. There it was crushed. Water was poured over it, and it was finally sifted in baskets and sorted by hand.

"I visited first," wrote Tavernier, "a mine in the territory of the kings of Visapoor, in a place called Raolconda, five days from Golconda, and eight or nine from Visapoor.

"All around the place where the diamonds are found the ground is sandy and full of rocks, and covered with coppice, somewhat like the environs of Fontainebleau. In these rocks are numerous veins, sometimes half a finger, sometimes a whole finger wide; and the miners have little iron rods, crooked at the end, which they thrust into the veins to dislodge the sand or earth in which the diamonds are found. . . . After this part of the work is done, the earth and sand is passed through two or three washings, and is carefully searched to see if it have any diamonds. It is from this source that the clearest stones and those of the finest water are taken. The only evil is, that to render more easy the extraction of the sand from the rocks, such strong blows are given with a great lever of iron that they shock (*étonne*) the diamond, and produce flaws."

Remarkable to relate, most of the buying and selling of diamonds in Tavernier's time was carried on by young boys. The French traveller gives a vivacious account of the *modus operandi* of these juvenile diamond dealers.

"It is pleasant," says Tavernier, "to see the

children of these merchants, and of other people of the country, from the age of ten to that of fifteen or sixteen, coming every morning and seating themselves under a large tree in the market place of the town. Each has his diamond weights in a little pouch hanging at one side, and at the other a purse attached to a girdle containing, in some cases, as many as six hundred gold pagodas. There they sit and wait until some one comes to sell them diamonds, it may be from the vicinity, or from some other mine. When anyone comes with something for them he places it in the hands of the eldest of the boys, who is, as it were, the chief of the band. He looks at it, and hands it to the one next him, and so it passes from hand to hand until it return to the first, not a word being spoken by any of them; the eldest boy then asks the price, in order to make a bargain, if possible, and if he happen to buy it too dear he has to take it on his own account."

When evening came the stones purchased were assembled, sorted, and priced. Then they were taken to the large merchants and sold. The profit was divided among the boys, the one who acted as chief receiving one-fourth per cent. more than the others.

Buying and selling is no longer entrusted to juveniles, but the primitive methods of mining, sluicing, sifting, and sorting described by Tavernier have remained practically unchanged until modern times, the only machinery utilized being a revolving endless chain fitted with earthen bowls to remove the water from the deeper pits. The pits are still only separated from one another by thin walls; some have steps cut in the sides, the diamantiferous earth being carried up in bowls on the heads of natives.

In some localities in India searching or mining for diamonds has been carried on at intervals for centuries; some mines have long been abandoned, while others,

formerly deserted, have since been reopened. From the mines of Kollur some of the most famous stones in history are said to have been extracted, notably the Koh-i-Noor and the Great Mogul. Tavernier, who referred to these mines as the Gani Coulour, estimated that about 60,000 natives were employed when he visited them. The Sambalpur mines, which have not been worked since 1850, are apparently among the most ancient in India. The Panna group was the most productive during the nineteenth century. Though there have been occasional rich finds, like the stone of 210½ carats found at Hira Khund in 1809, and that of 67 carats at Chennur in 1881, most of the old mines have long been abandoned, and the ancient glories of the mines of Golconda have departed, in all likelihood never to return.

As India came under British control diamond-mining declined. Perhaps it was because the supply was too uncertain to attract capital for organized working on Western lines. The autocratic power of the native princes was no longer available to compel their subjects to search for diamonds. Lacking capital, energy, or compulsory labour, the diamond industry languished. There were, too, other factors at work, chief of which was the competition of Brazil. The discovery of diamonds in South America was the beginning of the end of Indian diamond-mining. In these latter days few gems find their way out of the country, and so far as the world's supply is concerned the output from India is a negligible quantity.

As for Borneo, diamonds have been mined in that island ever since it was settled by the Malays. The references to Malacca in the works of the early writers, such as Garcia de Orta and De Boot,* refer in all

* *Gemmarium et Lapidum Historia*, Boetius de Boot, 1609.

probability to Borneo. The chief mines are situated on the banks of the River Kapnas in the west, and near Bandjarmassin in the south-east of the island. The alluvial deposits in which the diamonds occur are now, however, only worked by a small number of Chinese and Malays.

When, in the early part of the eighteenth century, some Brazilian gold-miners found a few bright, shining stones in the rivers of Minas Geraes, they had no idea of their value, and used them, it was said, for counters at cards. The story goes that one Bernard Lobo, who had travelled in the East Indies, was the first to identify these stones as diamonds, about the year 1725. The news spread slowly and was at first received with incredulity, but gradually it was realized that the age-old supremacy of the gems of the Orient was threatened. The new discoveries and larger supplies brought diamonds into more general use in Europe, and this in turn reacted by still further developing the trade in them.

The principal diamond-producing districts in Minas Geraes are Diamantina (formerly Tejuco), Rio Abaete and Bagagem at the headwaters of the Rio de San Francisco, and Grao Mogul, 200 miles north-east of Diamantina. The official announcement of the discovery of diamonds near Tejuco was made in 1729, and in the following year the mines were declared to be Portuguese Crown property. There was a Crown reservation known as the "forbidden district," 42 leagues in circumference, and from 8 to 16 leagues across. Within this area gold-mining was forbidden, and diamond-mining was only permitted under rigorous restrictions. But the diamantiferous gravels were fairly widespread, and it was impossible to prevent surreptitious digging. The illicit diggers and smugglers, or *Garimpeiros*, undoubtedly added

numberless stones to the world's stock which never appeared on official records. Herr von Tschudi narrates many amusing instances of the ingenuity of the smugglers.*

The Rio Abaete diggings were worked on a considerable scale between 1785 and 1807, but are now abandoned. Diamantina has long been the most important diamond-producing district in Minas Geraes. It occupies a barren and mountainous plateau, and the precious stones are found both on the tableland and in the river valleys that furrow its surface. The diamonds are found in three different positions and conditions. They are present in the gravels of the present rivers embedded in a clay-cemented conglomerate called *cascalho*, in *gupiarras* or terraces of similar material occupying higher levels in the ancient river valleys, and in deposits of coarser conglomerate called *gurgulho*, found near the surface of the plateau. The diamonds and heavier mineral substances, such as quartz, hornstone, jasper, etc., are found embedded in the red clay which cements the larger blocks together. As the heavy minerals in the terraces, which represent the remains of ancient river-beds, are more worn than those of the plateau deposits, and the gravel of the present river channels is more abraded than either, it is thought that the river deposits were originally derived from similar beds on the plateau, undergoing gradual concentration through the ages.

Diamond-mining in Brazil was for a long time carried on by negro slaves under the supervision of overseers who watched that no stones were concealed or stolen. Many of the slaves were adept thieves, so expert in fact that the utmost watchfulness was required to detect theft. Thieving was severely punished,

* "Travels in South America, 1857–1861."

and on the other hand honesty was encouraged to a certain extent by the custom of giving presents to the finders of gems. Diamonds were valuable and slaves were cheap, so that it was thought well worth while to give the finder of a stone weighing over one *oitava* (17½ carats) his freedom.

In those early days when the search for diamonds became organized the waters of the rivers were diverted into canals. The diamond-bearing soil was dug to a depth of about 10 feet and deposited in heaps near the washing-huts. These huts were provided with elevated seats for the overseers, who kept a watchful eye on the natives engaged in washing the diamantiferous earth in the *canoes* or long troughs. Brazilian methods have changed but little with the lapse of time. The *cascalho* is still excavated in the dry season and removed to a higher level, where it is afterwards washed out by hand in running water by means of *bateas* or shallow wooden basins. The terraces are worked when water is available by leading streams on to them. The washing of the plateau material is effected by means of water stored in reservoirs.

Of the production of diamonds in the Minas Geraes district it is impossible to form any reliable estimate, as no official returns have been published, but in modern times the output has certainly been equalled by that of the mines of Bahia. It is said that the first discovery of diamonds in the latter district was made in 1754, by a slave who noticed that the soil resembled that of his native Minas Geraes. But the Government prohibited diamond-mining about Bahia, and it was not until the nineteenth century that it really began.

In the year 1844 José Persira do Prado, journeying to the town of Bahia, camped on the bank of the Mocuge, a tributary of the Paraguassu, and quite accidentally

located a rich bed of diamonds. The news spread rapidly, the usual influx of treasure-seekers followed, and the camp of Santa Isabel soon grew into a town. It is said that there were as many as 20,000 miners working in the neighbourhood in 1845. Since that time the richest mines have been worked in the Serra de Cincora, which mountains are intersected by the Paraguassu and its tributaries. The diamonds occur in the river gravels and sands, just as they do in Minas Geraes.

As in other parts of Brazil, diamond-mining in Bahia is still for the most part carried on in the most rudimentary fashion. The *cascalho* is dug from the river-beds, stacked and washed once a week in sluices of running water. There it is turned over with a hoe and finally washed in *bateas*, the gems being picked out by hand. On the Paraguassu the diamantiferous gravel is dug from the bottom of the river by divers, or by men working under water in caissons or diving-bells. The stones, which are usually small, are sold to diamond buyers on the fields.

In the year 1827 diamonds were found near Grao Mogul, about 150 miles north of Diamantina, and by 1839 there were 2,000 persons working in the district. The beds were, however, superficial, and the diggings soon dwindled into insignificance. At the beginning of the year 1867 a *garimpeiro* (smuggler) found a diamond in the *gurgulho* near Bagagem, and a rush followed. But then came the discovery of diamonds in South Africa, and the downward trend of prices discouraged diamond-digging in Brazil. It is estimated that the total output of diamonds in Brazil, from their discovery to the beginning of South African competition, amounted to thirteen million carats. The rapid development and growth of the supply from South Africa, and the adoption of modern industrial and scientific

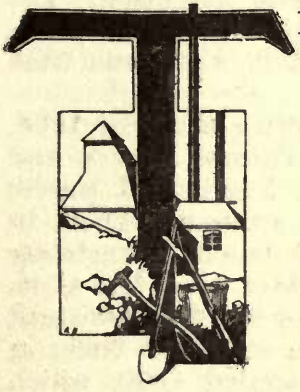
methods, has rendered the Brazilian output of comparatively little importance.

Brazilian diamonds, however, played an important part in adding to the world's stock, during the years between the falling off of the Indian supplies and the opening up of the diamantiferous beds of South Africa. As showing the comparative scarcity of diamonds during the early part of that period, there were, according to Mr. John Murray, so late as 1838, only nineteen gems of 36 carats and upwards in Europe, and it has been asserted that even at the time of the South African discoveries not more than a hundred stones of over 30 carats each were known.

During the above-mentioned period there were, too, remarkable fluctuations in the prices of diamonds. When Dom Pedro paid the Brazilian State debt in the precious stones the price in London fell almost one-half. The market value recovered, but declined again during the troubled period about 1848. After the American Civil War the price went up 25 per cent., and with the close of the Franco-Prussian War there was a further rise, which continued during the ensuing years of general prosperity and was checked only by the American financial panic of 1873. Then came the beginning of those wonderful discoveries in South Africa which marked an epoch in the history of diamond-mining and a revolution in the diamond trade of the world.

CHAPTER VIII

THE DIAMOND MINES OF SOUTH AFRICA



THE most stirring and important chapter in the story of the diamond mines is undoubtedly that relating to the South African fields. The finding of the earliest gems offers a series of romantic episodes only exceeded in interest by the discovery of the mines, the story of their phenomenal growth and development, and the wonderful way in which the world's chief diamond supply—an unending stream of jewels unequalled in history—has been produced and controlled.

The existence of diamonds in South Africa had long been a vague tradition among the natives and the white settlers. It was so far credited in the middle of the eighteenth century that on a missionary map published in 1750 we find the quaint inscription "Here be diamonds." But the legend was in a fair way to be forgotten during the successive waves of white immigration which spent themselves in the great Boer treks. In the year 1867, however, the children of a Boer farmer, named Jacobs, picked up a pretty shining stone on the banks of the Orange River close by. The children's bauble, which glittered and sparkled strangely, came under the notice of a shrewd compatriot, one

Schalk van Niekirk. He induced *vrouw* Jacobs to allow him to ascertain its value, and he passed it on to a trader named O'Reilly for that purpose. After eliciting a number of diverse opinions the stone was submitted to Dr. W. G. Atherstone, of Grahamstown, who pronounced it a diamond. It was eventually purchased by Sir P. E. Woodhouse, then Governor of Cape Colony, and was forwarded to the Paris Exhibition, where it attracted considerable attention. Dr. Atherstone predicted that more diamonds would probably be found in the vicinity, but it was some time before his prediction was fulfilled.

Several diamonds were found during the year 1868, at the confluence of the Vaal and Orange Rivers, and on the banks of the Vaal about Pniel, and public attention began gradually to be aroused. Then, in March 1869, a Hottentot shepherd named Swartzboy brought a large diamond to the store of a Mr. Gers, at the Hook, and demanded £200 for it. The assistant hesitated, and Swartzboy took the stone to Niekirk, already mentioned. Here he demanded £400, which Niekirk ultimately paid on the same day on which he himself received a sum of over £11,000 for the gem. This remarkable diamond, which weighed 83½ carats, sprang into fame as the "Star of South Africa," and was eventually purchased by the Earl of Dudley for the sum of £25,000.

The tidings of this great find spread far and wide. There was a headlong rush of diamond-seekers to the banks of the Vaal and the Orange. The first organized party of prospectors was led by Captain Rolleston, and included a couple of experienced Australian gold-diggers. They searched for months without success, but at length, on January 7, 1870, they washed out their first diamond at Klip Drift, near Pniel. A gravel-covered kopje proved to be richly diamantiferous.

News of this discovery could not long be suppressed. As a result, we read that " Every town and district in the Colony has sent its contingent to the army of workers at the Vaal fields. In May there were about 100 men at the diggings. Before the end of June there were 700, at the close of July over 1,000, and at present it is estimated that there are at the Klip Drift, Pniel, Hebron, and Kuskamana Fields no less than 2,000 men." * By the following April there were over 5,000 diggers along the Vaal, Modder, and Orange Rivers. The various diggings presented busy and animated scenes reminiscent of the great gold rushes of the " fifties." As the mining camps and settlements grew, the necessity of some system of governance became apparent. Each community of diggers elected its own committee, who framed a code of rules, adjusted claims, which were limited to 30 feet square, and levied fees. In the camps round Pniel, " President " Parker wielded considerable influence among the miners.

The sloping banks of the rivers were soon pitted with holes and shafts of all depths and dimensions, and the diamond-washing contrivances lined the water's edge for considerable distances. The separating apparatus was at first of the most rudimentary description. The shovel, the pan, or the Brazilian *batea* (wooden dish), and the cradle, were the principal implements employed. This alluvial diamond-mining was extremely laborious. Among the diamantiferous gravel and sand were huge boulders of basalt and metaphyre which had to be moved. The gravel and sand were shovelled into wheelbarrows and dumped either into heaps or direct into sunken troughs. Then this material was washed, generally in cradles which were fitted with two or three screens of wire gauze or perforated zinc, so arranged as to form graduated

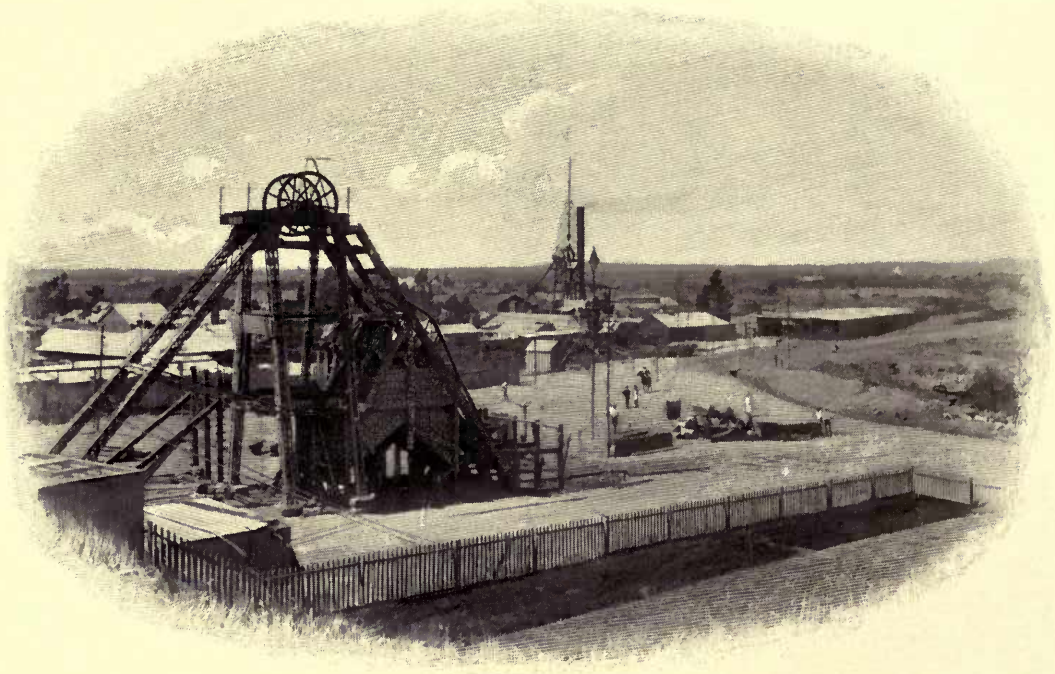
* *Grahamstown Journal*, August 12, 1870.

apertures. The larger stones were removed, and after the usual rocking process, accompanied by the addition of water, the finer material was taken and spread on a table or any flat surface, where it was carefully searched for diamonds.

On the whole, however, the output of diamonds at these early river diggings, as was only to be expected from such haphazard and unscientific prospecting and mining, was disappointing to the majority. In two years it was computed that only £300,000 worth of diamonds was extracted. Many hundreds of diggers gave up the quest in disgust, and the history of diamond-mining in South Africa might have faded into little more than a memory had not further epoch-making discoveries been made in that eventful year of 1870.

Hitherto it had been assumed that diamonds were invariably to be found in an alluvial setting, as indeed had been generally the case, not only in India and Brazil, but in South Africa itself. Consequently they were, as a rule, sought for in or about watercourses, old or new, and when the tidings came of diamonds being found at Jagersfontein, near Fauresmith, and far away from any river, they were at first accepted with reserve. But the news of further finds on the farm of Van Wyk at Dutoitspan, midway between the Vaal and the Modder, emphasized the possibilities of "dry diggings." It was said that diamonds were found even on the walls of Van Wyk's house, which was plastered with mud from the pond of Dutoitspan. Diamond-seekers crowded to the place in wagons, on horseback, and on foot, and in January 1871 the farm was "rushed" by the new-comers, who coolly proceeded to stake out claims. The bewildered Boer farmer Van Wyk found himself unable to deal with this new and perplexing problem, and sold his farm to an English company.

Adjoining Dutoitspan was another farm known as



General View, De Beers Diamond Mines, Kimberley.

Bultfontein, owned by one Cornelius de Plooy. So keen was the new demand for land in that vicinity, that although the presence of diamonds was purely problematical, one speculator purchased Bultfontein from the Boer proprietor on a Sunday, only to have the bargain set aside in favour of a rival syndicate who had persuaded the simple Boer vendor that the Sunday deal was illegal. North of Bultfontein lay the farm of Vooruitzigt (Look Forward), which was acquired by two brothers, Messrs. D. A. and J. N. De Beers, whose name was afterwards to become famous.

Although up to this time there had been no finds of any great importance, as a matter of fact these three farms included within their boundaries some of the richest diamond-producing areas the world has ever seen. Still, that was hardly suspected at the time, and when diamond-seekers came flocking on the land the proprietors allotted claims at a rental.

The miners found the work at the dry diggings comparatively easy after their arduous labours in excavating the alluvial gravel on the banks of the Vaal. Now they found the diamonds simply scattered among the red surface soil, some gems being so thinly covered that a heavy rainfall would expose them to view. Beneath the soil was a layer of limestone which, the diggers decided, was similar to the bedrock of the Vaal placers. Numerous small, yellow-tinted diamonds were found, and some larger stones, but the deposit was so shallow that a claim was soon exhausted. A digger, with the help of a sorter, could work out a claim in a fortnight, and would then abandon that and take up another. When a good deal of the ground had been ransacked, one of the workers decided to see what lay beneath the limestone. He found underneath a sort of conglomerate or breccia of yellowish colour, which, on being crushed and sifted, proved to

be rich in diamonds. Naturally when the knowledge of this discovery spread, as it did quickly, there was another rush for the abandoned claims to work the "yellow ground," as it was called.

Early in 1871 diamonds were discovered on the surface close to the farmhouse of Bultfontein. In May of the same year others were found on the De Beers' land, and two months later a second diamantiferous bed was located on the same farm. This last deposit was found on a gently sloping kopje which it was said had twice previously been searched for diamonds. According to another account the presence of the precious stones in depth was revealed by the sinking of a well. The diggers had reached a depth of 76 feet, and were amazed to see a diamond sparkling on the side of the pit.

By this time three distinct mining camps had sprung up in the vicinity, all lying within a circuit of three miles. These were: Dutoitspan; De Beers—also called De Beers' Rush or Old De Beers; and lastly, Colesberg Kopje, called De Beers' New Rush, or simply "New Rush." That part of the diamond diggings beyond the frontier of Cape Colony was claimed by the Orange Free State, but lay really in the territory of the Griqua chief Waterboer, who was nominally under British protection. After the discovery of diamonds the Orange Free State Government sent officials to collect taxes, but the diggers refused to pay them until the question of jurisdiction was decided. Sir H. Barkly, Governor of Cape Colony, was appealed to to arbitrate between the Orange Free State Government, the miners, and the natives. The contending parties finally agreed to submit the matter to a Commission, and the upshot was that the British flag was hoisted at the new "dry diggings" at Colesberg Kopje, then renamed Kimberley, in November 1871.

Although the manual labour involved in diamond-mining at the " dry diggings " was at first less laborious than at the river diggings, there were difficulties to be overcome. Those miners whose claims lay on the side of a kopje or ridge cut their way in by means of adits or tunnels; others dug downwards in a series of steps; but the majority sank perpendicular shafts, which they ascended and descended by means of notches cut in the sides. The excavated material was hoisted to the surface in a bucket by means of a rude windlass worked by a native.

After extracting any visible diamonds the pieces of " yellow ground " were roughly pulverized by beating with shovels, mallets, or clubs, and then passed through a coarse sieve to remove the larger stones. After that the " ground " was carefully sifted a second time through a fine rocking or swinging screen. When the screen was swung rapidly the sand passed through the meshes, leaving a mixture of fragments and pebbles of limestone, talc, and basalt, with a sprinkling of garnets, peridot, and, occasionally, diamond crystals.

It was soon noticed that the diamantiferous areas at Jagersfontein, Dutoitspan, and in fact at most of the " dry diggings, " were roughly circular in form, and that some of them occupied the sites of the " pans " or depressions so common in South Africa. As the numerous pits were excavated deeper and deeper it was discovered, too, that at a depth of about 50 feet the yellow ground was succeeded by a hard, bluish-green, serpentinous rock. The diggers jumped to the conclusion that this at all events was the barren bedrock. But once again, as in the case of the " yellow ground," they were agreeably surprised to find that the new " blue ground," as it soon came to be called, was also rich in diamonds. The " yellow ground " proved to be merely a decomposed form of the " blue ground,"

which, as the South African matrix of the diamond, has added so much to the world's wealth of gems.

In the vicinity of Dutoitspan there were five of these circular diamantiferous areas within a circle three miles in diameter. The Dutoitspan basin occupied twenty-three acres, but its small surface yield caused it to be little worked until about 1880. The area of the Colesberg Kopje (afterwards Kimberley) Mine was ten acres. Within these limits the claims were remarkably productive. Tidings of their richness spread, and lost nothing in the telling. Men flocked to the diggings from all points of the compass and from all parts of the world, and within a comparatively short space of time there were 50,000 diamond-seekers in the district. The various canvas camps grew closer together and were gradually transformed into a town of wood, corrugated iron, and brick, surrounded by the huts of the natives. Such were the beginnings of Kimberley, from that time the centre of the greatest diamond-mining district ever known. The town owed its name to the first Earl of Kimberley, during whose term of office as Secretary of State for the Colonies the mines were, in 1871, taken under the protection of the British Government.

Every claim in the diamantiferous areas was rapidly taken up, and mining was vigorously prosecuted. Each holding was an independent pit sunk into the blue ground, and the various mines soon presented the appearance of huge basins studded with workings all at different levels, with men toiling like ants in an inverted ant-hill open to the sky. Roadways were left to provide access to the claims, from which the diamantiferous rock was hoisted by bucket and windlass. The friable nature of the blue ground soon began to cause trouble, caving in as it did on the heads of the diggers. The pits, too, were sunk so close together that

the dividing walls often gave way. But, worst of all, the roadways across the mine often collapsed, possibly because the owners of the adjoining claims, in working to the bounds of their allotments, undercut them. It was no uncommon sight to see a loaded cart, with driver, mule, and all, fall into a yawning pit as the road caved in. The roads were patched up for a time, but ultimately they all crumbled into debris at the bottom of the great open pit, which, in the case of the Kimberley Mine, was an oval abyss 1,000 feet in length by 600 feet in width.

The problem of transporting the broken blue ground from the pit or claim to the surface or edge of the great crater at once became acute. It was ingeniously solved by the erection of a huge timber staging round the mouth of the mine, consisting of two, and in some places three, platforms—one above the other. The upper tiers were connected by strongly anchored wire ropes with the claims in the centre of the mine, and the lower platforms in similar fashion with claims near the margin of the pit. By means of windlasses, ropes, and raw-hide buckets suspended from the wire ropes on pulleys, the blue ground was hauled to the platform, dumped through chutes into bags, and carted to the " floors " where the stuff was sifted and sorted. The raw-hide buckets were allowed to slide back to the claims by gravity down the slanting ropes, which radiated in every direction like the strands of a cobweb.

With the deepening of the mine, horse-whims—first introduced in 1874—gradually replaced the hand tackle used in winding or hoisting the buckets of blue ground. Then in the following year came the first steam winding-engine to be employed in the diamond fields. But the use of steam did not spread very rapidly, partly because of the cost of fuel—coal was £30 per ton—but

primarily because the continuance of the supply of diamonds was considered too uncertain to justify the installation of expensive plant or machinery. But as the workings descended lower and lower, the blue ground showed no signs of giving out, and geologists put forward the theory that the mines were in reality "pipes" or funnels in the rock, of volcanic origin, and in all probability of great depth. This theory has since been confirmed, as also the volcanic nature of the diamantiferous matrix or blue ground.

While the sinking of the pits was progressing there had been a marked advance in the method of extracting the diamonds from the blue ground. For the first three years after the opening of the mines the treatment, which resembled that used at the River Diggings, was crude and wasteful. Many of the smaller crystals were left among the refuse, and there was a further loss through theft. In 1874 water was introduced into the process of concentration, and by building dams and sinking wells an increased water supply was secured. At first cradles or rockers were used as in gold-washing, but these were soon replaced by puddling troughs—circular troughs in which the watery debris was stirred by horse power—the heavier concentrates settling at the bottom.

It had been observed that the blue ground crumbled with exposure to the weather after a period varying with the hardness of the breccia. It was realized that to take advantage of this natural disintegration would be cheaper than the usual methods of pulverizing. But nature was too leisurely in her processes, and the ordinary claim-owner was dependent on quick returns. Only the larger companies could afford to allow large stocks of blue ground to lie for weeks or months exposed to the action of sun, wind, and rain. The changing conditions, which necessitated the sinking of increased

capital, forced the consolidation of claims, despite the original prohibition of "claim-blocking."

As the workings sank to a still lower level the difficulties of the diamond-diggers increased. First of all there was the problem of draining what was practically a huge open sink, but even more serious were the frequent landslips. The soft rock surrounding the mine had been imprudently cut vertically, and, as the blue ground was removed, repeatedly caved in, burying the adjacent workings in shaly debris. No single claim-owner could bear the cost of removing the dangerous reef. Co-operation became inevitable, and a Mining Board was formed. This body, however, was not very successful in dealing with the practical problems involved. The pumping of the mine was a comparatively simple matter, but despite many costly experiments the sides continued to fall in. In 1883 the Board became bankrupt.

By that time the Kimberley pit had reached an average depth of about 400 feet. Masses of barren rock known as "reef," which had been left standing in the mine, also collapsed. Obviously open pit-mining in the Kimberley crater had become impossible. In the minds of many observers the Kimberley diamond mines were doomed. Though they were known to contain stones which in the aggregate represented a fabulous value, it was feared that the practical difficulties and the consequent cost of obtaining the gems would make the venture a highly speculative proposition. For even in diamond-mining profit and loss is the deciding commercial factor. To the individual claim-owner the prospect was hopeless. The only possibility of success lay in the carrying-out of deep and extensive underground workings by a wealthy syndicate.

A preliminary venture was undertaken by Mr.

Edward Jones, a mining engineer, under whose direction a timbered shaft was sunk through the mass of fallen reef on the Central Company's claims in the deepest part of the mine. When the blue ground was reached levels were driven in several directions. This device saved the sinking of costly shafts in the reef outside the mine, and its cost was defrayed by the diamantiferous material excavated in opening up the levels and cross-cuts. A number of similar shafts were sunk in other parts of the mine, but although they helped to tide the mines over a critical period, it was realized that they were but temporary expedients.

Preparations were made, therefore, for future operations by sinking shafts in the reef outside the margin of the open mine. Vertical shafts were sunk by the Central and French Companies, and tunnels driven from them into the blue ground. The other Kimberley mines, the De Beers, the Dutoitspan, and the Bultfontein, also had to adopt underground mining owing to the repeated falls of reef. In the Kimberley Mine itself, after a short time, the pillars of blue ground that had been left to support the different levels began to show signs of crushing, and the miners were only withdrawn in time to avert serious disaster.

The whole system of workings with which the blue ground was honeycombed fell in, and the consequence was that towards the close of the year 1888 the whole mine had to be reopened from top to bottom. The errors in engineering which had led to this deplorable result had been accentuated by the want of co-operation between rival owners, there having been repeated disputes regarding encroachments.

Clearly some scheme of amalgamation was imperative. As we have seen, the process had already begun on a limited scale. There were two chief factors which made it inevitable. First there was the necessity

of unification to secure economy and efficiency of working, which were impossible under multiple management, even apart from the question of capital. The other factor was also an economic one. The South African mines had provided a notable increase in the supply of diamonds, and the natural tendency was towards a fall in prices, unless the supply were regulated or controlled in consonance with the demand. This was, of course, impossible under a competitive system. But already there were shrewd brains at work which foresaw in this control of the chief supply, and therefore of the price, of diamonds, the chief advantage of consolidation or amalgamation of the mining interests. The failure of the open pit working and individual-claim system made the matter one of paramount urgency, while it in no wise discouraged those who knew or had confidence in the practically inexhaustible resources of the diamond-mines.

Of the small group of men who foresaw all this and worked steadily towards the attainment of these ends, undoubtedly the outstanding figure was Cecil John Rhodes. He was instrumental in floating the De Beers Mining Company, which absorbed the De Beers Central and then the Oriental. While Cecil Rhodes was thus engaged on the De Beers Mine, a shrewd financier was also at work in the Kimberley. Barnett, or as he was more familiarly known, "Barney," Barnato as early as 1880 had secured a number of claims in the Kimberley "pipe" and floated a company under the name of the Barnato Diamond Mining Company. In 1881 he floated several other companies, and continued his policy of amalgamation until he gathered into one concern, known as the Kimberley Central, every claim in the mine except those owned by the French syndicate.

Cecil Rhodes, with the foresight and broad grasp of

great problems which were characteristic of the man, planned a combination of interests in the African fields sufficiently strong to control the diamond trade of the world. But this was only a means to an end. His immediate interest in the acquisition of wealth was really subordinate to his sense of the power of which it was the symbol, the power to realize his dreams of a Greater South Africa under the British flag.

These two men, Rhodes and Barnato, were then working on parallel lines, each concentrating power as the opportunities of acquiring fresh interests occurred. Commercial considerations demanded that the two great combines must also be merged, else it would be simply a case of inflating and accentuating the rivalry and competition. But while Rhodes was obsessed by his colossal schemes of Empire-building, Barnato made no secret of the fact that he was solely concerned with the commercial possibilities of amalgamation. The former sought to merge the whole South African diamond-mining industry into the De Beers Consolidated Mines, a concern organized in 1888 with a very comprehensive prospectus. Barnato wished to confine the interests he represented to the mining of diamonds, without incurring other liabilities. The contest between the two interests was long and keen, but Rhodes finally succeeded in obliging the Barnato interests to agree to a merger. A minority of the shareholders of the Kimberley Central succeeded in procuring an injunction restraining the merger. This did not, however, deter Rhodes and his associates, who accomplished their object through the liquidation of the Kimberley Central. The property and assets of the mine were then purchased by the De Beers Consolidation for the immense sum of £5,338,650. A paramount interest was secured in the Griqualand West Mining Company, which owned about half the Dutoitspan

"pipe"; and a perpetual lease of the Bultfontein Mine was also obtained. According to Mr. Gardner F. Williams, in his "Diamond Mines of South Africa," properties costing upwards of fourteen millions sterling were acquired by the De Beers group. When the De Beers Consolidated Mines Company was promoted all save twenty-five of the shares were held by four men in the following proportions: Barnett J. Barnato, 6,658; Alfred Beit, 4,439; Cecil J. Rhodes, 4,439; F. S. P. Snow, 4,439. These four men were the first directors and life governors of the corporation, and so controlled the diamond industry of the world.

This great combination of interests transformed the diamond mines of South Africa from a condition of uncertain production and speculative prices, liable to sink with an uncontrolled output until it became a risky and even unprofitable undertaking, to one of international importance, ranking among the staples of commerce.

In the years between 1873 and 1880 the diamond production of South Africa probably did not average more than from 1,000,000 to 1,500,000 carats. In 1888 it had increased to 3,565,780¾ carats, which at an all-round valuation of 20*s.* 2½*d.* per carat was worth £3,608,217. As soon as the consolidation was effected the prices of diamonds were advanced. By the middle of the year 1889 stones were selling at 30*s.* per carat, and this was only the beginning of the upward movement. The De Beers management formed a syndicate for the purchase of the output of the mines and the sale of the diamonds in London. The syndicate took over the product at an agreed price under contracts for periods ranging from one to five years.

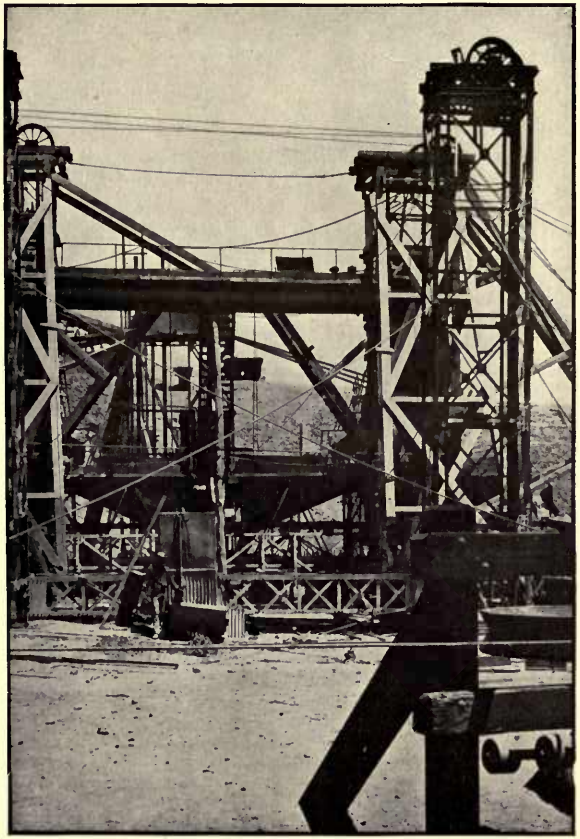
With regard to the other mines taken over by this great corporation, its policy in limiting the total output may be judged from the words of the late Cecil Rhodes,

referring to the Dutoitspan Mine: "It is too poor to work and too rich to allow others to acquire it." Having secured a controlling interest in this mine, the De Beers Company closed it down for several years until all the outstanding shares were bought in. The Bultfontein Mine—which in 1887 had reached a depth of 460 feet, but like the Kimberley was covered with fallen reef—was also closed down for some years.

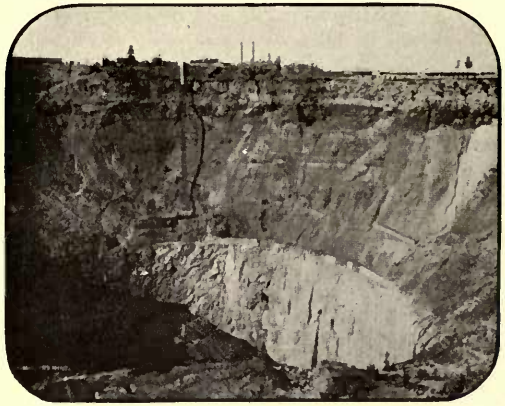
Meantime the Jagersfontein, which was actually the first of the dry diggings to be discovered, was being worked with a fair amount of success. In 1888 the New Jagersfontein Company absorbed the various claims, and a controlling interest in this company was secured by the De Beers Consolidated Mines. The shape of the mine itself is a rough oval about 1,500 feet by 2,000 feet. It has been skilfully worked by means of concentric terraces to a greater depth than any other of the open mines. The yield of diamonds per load (one-tenth of a carat) is very small, but the diamonds produced are the finest in South Africa.

It might seem incredible that another diamantiferous pipe could exist within a mile of the Dutoitspan and remain unknown for twenty years. Yet this was the case with the Premier, or Wesselton, as it was subsequently called, after Mr. J. J. Wessels, the owner of the Benaaudheidfontein farm. Diamonds were located on the farm in September 1890, and the "pipe" was estimated to occupy an area of 24 acres. The ubiquitous De Beers purchased the property with some mining reservations in 1891, but did not assume full control until 1896. The Wesselton Mine has proved one of the most profitable of the De Beers group. Although the yield per load has only been moderate, it seldom fluctuates, and the aggregate output has been large.

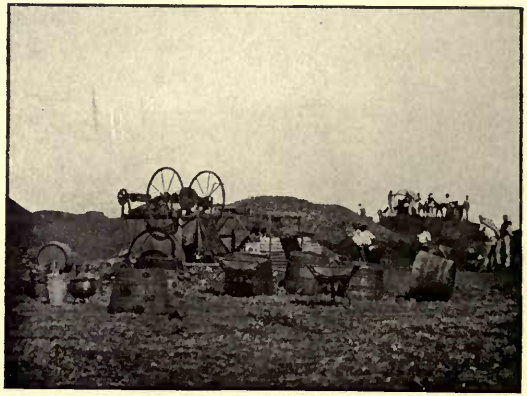
In an industry such as diamond-mining, where the



De Beers Washing and Concentrating Machinery.



The "Pipe," Kimberley Mine.



River Washings at Klipdam.

removing the blue ground while loose is very low. On each level the operation is carried farther back, that is, nearer the shaft, than on the level below. The diamantiferous material is thus being continuously excavated from the farther side of the mine and removed to the rock shaft on the opposite side. The progress of the work on the different levels might be compared to a series of huge stopes or steps, the overlying debris sinking continuously but regularly, as it is allowed to break down the blue ground, and reaching its lowest point at the bottom level on the side farthest from the shaft.

For many years the miners were liable to be overtaken at any moment by what are called " mud rushes." The intruding material, a mixture of decomposed shaly debris and water, would burst into the workings and overwhelm the miners without a moment's warning; but this danger has now been minimized by an elaborate system of drainage. The workings in the De Beers Mine in the year 1904 had reached a depth of 2,076 feet, while three years later the lowest level of the Kimberley was being worked at a depth of 2,520 feet, or almost half a mile.

In the principal diamond mines the winding shafts are vertical, and mostly rectangular in plan. The De Beers rock shaft was the first large shaft of its kind, and has served as a model for subsequent sinkings. It measures 20 feet from end to end and 6 feet across, and is divided into four sections—two for the skips in which the blue ground is hoisted, one for the cage conveying men and materials up and down, and the fourth, intended for the pumps, is also utilized for ventilation.

For all underground service and wherever mechanical motive power is requisite, steam has been replaced by compressed air, and air by electricity. Lighting,

drilling, haulage, telephoning, signalling, and many other functions are now performed by electricity. Trucks holding 16 cubic feet of blue ground, electrically propelled and automatically coupled, are, when they reach the end of a level, mechanically tipped so that the blue ground slides down a chute into a skip. This skip holds six truck-loads, and when full is whisked off on its swift half-mile flight to the surface.

In the extracting and treatment of the blue ground at a modern diamond mine, labour-saving and therefore cost-saving machinery is employed on a vast scale, and even the great free forces of nature are utilized. Only in this way can diamonds be economically produced, as immense masses of material have to be handled. At some of the great mines 5,000,000 truck-loads of material are treated in a year, and from this great mass, which would form a block larger than St. Peter's, Rome, only a few bucketfuls of gems are extracted.

When the skips reach the head of the shaft their contents are, again automatically, tipped into side-tipping trucks. These latter are drawn away in a continual procession, by means of an endless wire cable, along the tram lines leading to the far-spreading " distributing-floors." These are simply great stretches of veld carefully fenced off, and resemble nothing more than farm land, newly ploughed and harrowed. The blue ground is spread out at the rate of a truck-load to every 20 square feet or so, and is left there for the sun and rain to work their will upon. The diamantiferous material is hard to begin with, but slowly crumbles under the disintegrating influence of the weather. The natural process is, however, too slow for commercial requirements—it takes three, six, or even twelve months—and is hastened by steam ploughs or wheeled harrows, drawn by traction engines, and by watering during prolonged drought. The idea of wealth

beyond the dreams of avarice lying concealed in these vast expanses of broken earth makes them interesting, but does not succeed in making them picturesque.

The broken blue ground after its long spell in the open is taken in trucks to the concentration plant. There it is passed through perforated cylinders, the fine material going forward into the washing-pans, the coarse being searched for diamonds and then passed through crushers. The washing-pans are shallow, circular troughs containing muddy water, which is found to be most effective. Great toothed arms revolve in the pans, and the diamonds and other heavy minerals are swept outwards to the edge. These "concentrates," as they are called, having been largely cleared of waste, are by this time very valuable, and are taken in locked trucks to the "pulsators." These are an ingenious contrivance for effecting a further concentration of the diamantiferous material, consisting of sloping screens or tables shaken laterally to and fro under a stream of water.

The final separation of the diamonds from the concentrates was, until within the last few years, effected by hand-picking. But even this important and delicate process is now performed by machinery. Owing to the remarkable discovery that diamonds alone of all the minerals in the blue ground will adhere to a greased surface, it has been found possible to make the sorting automatic. The concentrates are washed down a sloping table of corrugated iron which is smeared with grease, and it is found that practically all the diamonds adhere to the greasy surface while all other minerals are washed past it. The grease loses its power to catch and hold the stones after a time, and it is then scraped off, together with the diamonds adhering to it.

From the sorting tables the diamonds are conveyed daily to the general office under an armed escort and

SEARCHING TABLES, DE BEERS MINES, KIMBERLEY.

UNIVERSITY OF CALIFORNIA

delivered to the officials in charge of the valuation department. There all foreign matter is removed from the stones by boiling them in fluoric acid or a mixture of nitric and hydrochloric acids. When they are thus cleansed they are carefully sorted by expert valuers for size, colour, and purity, and made up for sale. Formerly the product was sold in Kimberley to the representatives of the leading diamond merchants of the world. But, as we know, the principal producers have for many years sold their annual output in advance to a syndicate for disposal in London.

Most of the unskilled work in and about the South African diamond mines is done by natives, and a good deal of convict labour is employed. The majority of the white miners have their homes in Kimberley and are of English birth or descent. Wages are fairly high, ranging from ten to fifteen shillings per day for surface workers and from sixteen to twenty for mechanics and underground workers. The natives are kept in compounds under quarterly contracts. During the three months of their agreement they are not allowed to pass out of the compound without a special permit. Before being allowed out on leave they are kept for several days in a detention-room under the strictest supervision. This is found necessary as there have been numerous instances of these Kaffir boys having swallowed diamonds. Their clothing is searched and they are allowed to take away only soft goods. Even boots are banned, as offering too convenient a hiding-place for diamonds.

Pipes similar to those near Kimberley have been found in other parts of South Africa, but though geologists tell us that all are connected with great volcanic outbursts, which drilled these peculiar craters through the later formations, comparatively few of the pipes are diamantiferous. Some of the most

notable of the South African diamond mines besides those already mentioned are the Roberts-Victor near Boshof, the Voorspoed, the Koffyfontein, and last, but not least, the Premier.

During the years of remarkable and world-wide prosperity from 1889 to 1903 the De Beers Consolidated Mines and the allied Diamond Syndicate continued to control the South African output and the diamond trade of the world. In 1904, however, a new rival appeared on the field in the shape of the great Premier Mine of the Transvaal—a young giant then only recently discovered.

It was known that there were diamonds in the Pretoria district as early as 1897. Mr. T. M. Cullinan, who had been prospecting in the vicinity, came to the conclusion that there were diamonds on the land of Joachim Prinsloo, a Boer farmer. Cullinan wanted an option on the property to examine it before purchasing, but Prinsloo would only sell outright for £25,000. Then came the Boer war, and negotiations were suspended. After the war, negotiations were resumed, but the shrewd farmer raised his price to £50,000—for land that had cost him only £500 ! So confident was Cullinan in the possibilities of the land that he closed with Prinsloo, and commenced operations forthwith. The first boring yielded no diamonds, but the second produced eleven, including one of sixteen carats. The Premier Mine, as it was named, justified its owner's optimism, and was formed into a limited company in 1904.

The Premier was found to be a huge volcanic chimney or pipe of diamantiferous earth, similar to those of Kimberley but much larger, the pear-shaped basin having an area of 80 acres. Unlike the Kimberley mines, however, it had no strata of limestone, but the crater was covered with a red clayey soil 5 or 6 feet

thick. Beneath this lay about 30 feet of yellow ground which gradually merged into the blue. The blue ground of the Premier is much softer and more friable than that of the Kimberley mines, and does not need weathering, but is conveyed direct to the elaborate separating plant. The rim rock, on the other hand, is very firm. Being an open-cut mine, less machinery is required and the working costs are less in the mine itself than in the more complex subterranean workings of the De Beers group. The area of the Premier is, too, so great that it can be operated cheaply as an open working for many years to come.

In 1904 diamonds aggregating 750,000 carats were taken from the surface workings, and by 1907 the output had reached 1,890,000 carats. Constant additions were made to the concentrating plant, which for the year ending October 31, 1908, washed nearly 27,000 loads per day. This capacity has since been increased to over 40,000. At first the washings were unusually rich, averaging nearly 1½ carats to the load (of 16 cubic feet, or approximately a ton), but the percentage of stones has steadily decreased while the total yield has increased. At the Premier Mine the Elmore process, used elsewhere for ore treatment, has been introduced. Oil is employed to float off the materials which adhere to it, while the other materials remain in the water, the oil being separated from the water by centrifugal action. Some of the Premier crystals have a peculiar laminated appearance, others have an oily lustre and are quite blue; but for the most part they are fine stones, and many large ones have been found. It was in the Premier, the greatest of diamond mines, that the Cullinan, the greatest of diamonds, was found.

One evening in January 1905, Captain Frederick Wills, the mine manager, was leisurely picking his way down the broken surface of the open workings. With

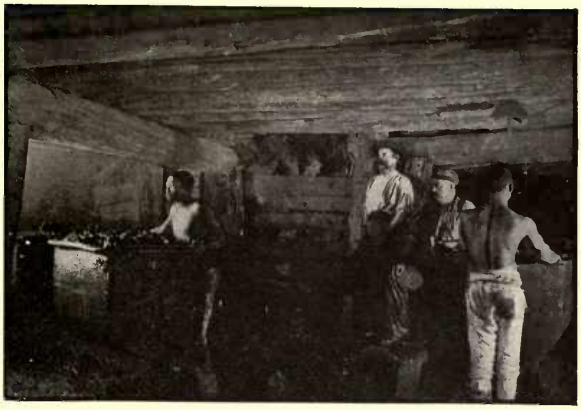
the quick eye of the expert diamond-seeker he suddenly caught a gleam in the rough face of the slope he was descending. Stooping, he picked from its bed in the blue ground a huge crystal. It looked like a piece of ice or rock crystal, but Captain Wills realized that it was an enormous diamond. He walked on to the company's office, where Mr. Cullinan and Mr. McHardy, the general manager, were inspecting the day's yield of gems. The mine manager produced his find, and the three men stared at it and each other in silence for a few tense moments. They could not take in all at once the magnitude of the find, or realize that it meant fortune for themselves and fame for the mine.

This immense diamond—the greatest ever known—weighed 3,025¾ carats, or nearly 20 oz. troy, and measured 4 inches long by 2½ inches wide by 1½ inches thick. After being exhibited at Johannesburg and insured for a quarter of a million sterling, it was sent by post to London. There it was found that its great size and price rendered it practically unsaleable.

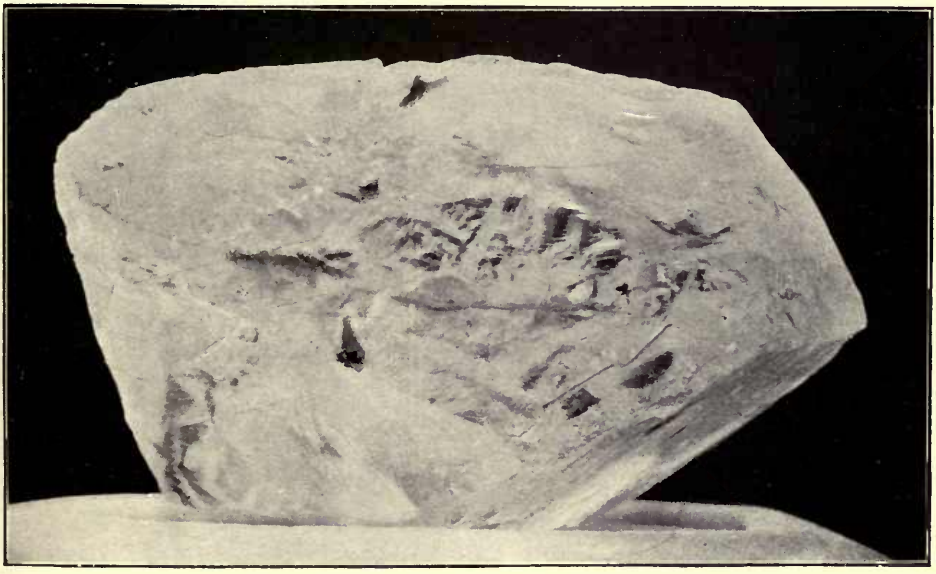
Ultimately it was purchased by the Transvaal Government, and was presented to His Majesty King Edward VII. on November 9, 1907. It now occupies a place of honour in the jewels and regalia of the British Crown.

The output of the Premier Mine was formerly taken to Kimberley fortnightly, and sold to the Syndicate. The increase in the yield of this great Transvaal mine was, however, so phenomenally rapid as to make it a formidable rival to the De Beers group. In the year 1907 the total South African production was 5,002,968 carats, of which little more than one-half was from the De Beers mines. It was evidently feared that this expanding output from the Premier would affect the maintenance of prices, and it was arranged that the Syndicate should include the Premier yield in

UNIV. C
CALIFORN



UNDERGROUND WORKINGS, DE BEERS MINE.



THE CULLINAN DIAMOND (NATURAL SIZE).
From a photograph by Sir William Crookes.

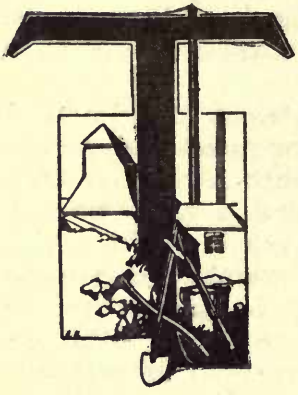
its sales. The agreement was, however, a short-lived one.

As showing the marvellous expansion of the diamond industry in South Africa, it may be said that for the ten years between 1898 and 1907 the total output was 31,000,000 carats. During the same period the price at the mines rose from 28*s.* 6·2*d.* to 64*s.* 9·74*d.* Adding to the above total, for diamonds from other sources and for thefts, and for the 57,409,613 loads of blue that the De Beers mines had "in sight," another 17,000,000 carats, we have on the basis of the average value realized by De Beers a grand total of £78,000,000 sterling produced in ten years.

As to the future of the South African mines and of diamond-mining generally, it would be rash to prognosticate. The story of the mines of South Africa has been one of phenomenal development and a meteoric rise to a position of dominance in the markets of the world. Whether or no that position will be maintained remains to be seen. Present evidence points to the probability that it will, at least for some time to come. But one never knows—a single new discovery of importance might revolutionize everything. One factor alone remains constant, or varies but little, and that is the world's insatiable demand for diamonds.

CHAPTER IX

DIAMOND CUT DIAMONDS



THE qualities which render a diamond so transcendently beautiful are explained by the scientist to his own satisfaction as according with those laws of optics which cause it to refract rays of light. Light falling vertically upon the surface of the diamond enters and passes on, we are told, in a straight line, but of those rays which strike it slantingly some are reflected and some enter. Those which enter the gem are refracted or bent, as are all rays when they pass into a transparent medium that is denser than air. All precious stones possess this attribute, but diamonds in a supreme degree.

The light which falls upon the outer facets of the gem and is flashed back is called the surface brilliancy, while that which enters is called the internal brilliancy. The very appearance of the rough diamond has always suggested the possibility of greater potential brilliance, and to increase that is the object of cutting and polishing.

The diamond, as has been said, is the hardest of all things, but all diamonds are not equally hard. African stones are softer than Brazilian, and Indian are harder than either ; whilst those of Borneo and Australia

are said to be the hardest of all. The " nyf " or skin of the crystal is harder than the interior, and, strange to say, there is a distinct " grain " in diamonds just as in wood. Cut along the grain and you make little impression ; it must be cut across.

It will be seen, then, that the task of cutting this thing of adamant, the diamond, is no simple one. It was a problem that for centuries baffled human ingenuity. Eventually it occurred to some genius among the ancients that the only substance hard enough to make any impression on the diamond was—the diamond itself ! Then for many more centuries the simple rubbing of one diamond against another, known as " bruting," was the only method known of altering or improving the shape or lustre of the stone.

The discovery of the art of cutting and polishing diamonds is usually ascribed to Ludwig van Berghem, otherwise Louis de Berquem, of Bruges, and to the year 1465. But long before that time stones were cut in India and China, and there were said to be diamond-polishers in Nuremburg in the fourteenth century and later in Paris, and also Lisbon, where the Jewish cutters hailed from Alexandria. Still Berquem undoubtedly perfected the polishing wheel to be used with diamond dust, and also the arrangement of the facets. The diamond-cutting industry flourished at Bruges under the Dukes of Burgundy, but was afterwards transferred to Antwerp. After the capture of that city by the Duke of Parma in 1585, the diamond-cutters fled to Amsterdam, which has ever since been the headquarters of the industry. There were seventy-five diamond-cutters in Paris in 1700, but political unrest drove them to the Netherlands. To-day there are more than sixty diamond-cutting establishments in Amsterdam alone, giving employment to over 9,000 people.

It was a Venetian lapidary, by name Hortensio

Borghis, who, according to Tavernier, was employed to cut the great diamond seen by the latter in the treasury of Aurangzeb. This stone has been variously identified as the Great Mogul and the Koh-i-noor, but whichever it was, the work of cutting nearly cost the poor Venetian his life. The Hindu potentate accused him of having spoiled the diamond, but allowed him to forego the inconvenience of losing his head in consideration of a payment of 10,000 rupees.

The ruling idea of the early cutters appears to have been to polish the surface of the crystal with a minimum loss of weight. In order to concentrate the reflective power of the stone near the face, they ground off the apex of the crystal to a flat facet, forming what we now call the " table," and took the tip off the corresponding point. This produced a square jewel with a large and small facet parallel to each other. To further increase the surface reflections this form was later changed to that of an octagon. From these comparatively simple forms there was, in the desire to increase the brilliancy or dispersion of the light rays, a gradual increase in the number of facets.

Material improvement was, however, slow. Large stones were scarce in those days, and the aim of the cutter was to produce as large a cut jewel as possible from the crystal. The number of facets in the old form of square-cut brilliants was gradually increased to thirty-four, and eventually to fifty. Then the lines along which diamond-cutting began to develop gradually took two different directions, and resulted in the production of the brilliant and the rose.

The early English round-cut brilliant contained in all fifty-eight facets, and was the most perfect arrangement devised up to that time. The brilliant-cut diamond is based on the natural form of the diamond, which is an octahedron, resembling a double cone with

a common base. The upper pyramid or cone is cut off close to the base to form the flat upper facet or " table," and the lower or " culet " side has only the apex removed. The four superior edges, or ribs, and the four inferior edges, are then removed in such a way that the table and the culet are outlined as regular octagons. Lastly, the eight facets which outline the table are cut, each into four facets forming the *crown*, and the eight faces of the culet are divided in the same manner to form the *pavilion*. The re-cut brilliant with its sixty-six facets is one of the most perfect forms for the display of the beauties of the diamond. The rose-cut diamond is flat underneath, the upper or convex part being cut with a number of facets arranged round a central facet. If it has twenty-four facets it is known as a " Holland Rose," if eighteen or twenty a " Semi-Holland," and if only twelve or even less an " Antwerp Rose."

Diamond-cutting has nowadays developed into an art demanding extraordinary delicacy and skill, and the finished gem frequently approaches the ideal in its combination and distribution of light and brilliance at all distances from the eye.

Rough diamonds direct from the mines are, for gem-cutting purposes, divided into two classes, " close " and " cleavage." The first named are naturally of such a shape as to be ready for cutting. " Cleavages " are crystals of a shape unsuitable for cutting as they stand. They are split before passing into the cutter's hands. The cleaver or splitter must have good judgment and a sound experience of rough diamonds. He has to decide how to divide the stone so as to retain the largest size and the most brilliant effect, and to eliminate any flaw. The operation of splitting seems simple enough. The stone is set and fixed in a holder, and with the edge of another diamond secured in

similar fashion, a notch is cut in the first in the direction of the cleavage plane. Then the blunt edge of a flat piece of steel is placed in the notch, the other end is struck a smart tap with a hammer, and hey presto! the crystal is split in two, the sides of the cleft being smooth and shining.

The diamonds are then passed on to the cutter. The "cutting" of a diamond really consists in the preparation of the stone for the final process. This is effected by setting one uncut stone in a turning-wheel and another in a holder. The latter is held against the rotating stone in such a way that each grinds the other down to a "girdle," from which they are rounded up to a low dome for the "table" side and a higher one for the culet side. The essential part of this process lies in roughing out the projected outlines of the finished brilliant. It cuts to dust about 15 per cent. of the total weight lost in the entire process, which loss (not waste, as all dust is saved) has by the latest methods been reduced from 60 to 50 and even 40 per cent.

The polishing room is the most interesting department of any of the great diamond-cutting establishments in Amsterdam. Men are seated at benches flush with the surface of which horizontal steel discs rotate at an immense speed. These wheels are hackled or grooved to retain an abrasive mixture of diamond dust and oil. The polishing of a diamond really includes the grinding of the facets as well as the polishing, the stone being pressed down upon the wheel at the exact angle required for the facet.

The cutting of the great Cullinan diamond was one of the most remarkable feats in the history of the industry. This responsible task was entrusted to the firm of Asscher in Amsterdam, who carried it out with conspicuous success. There was a flaw in the interior of the uncut stone, and it was decided to make one

principal cleavage which would pass through the flaw. After the usual incision was made, Mr. J. Asscher, in the presence of three representatives of the British Government, and after a period of suspense, successfully accomplished the cleavage. For the cutting and polishing, special tools were prepared. On account of the great size of the two principal Cullinan gems it was decided to increase the number of facets to seventy-four in the largest, which weighed 516½ carats, and sixty-six in the second, of 309$\frac{3}{16}$ carats.

The story of the celebrated diamonds of the world, if told in detail, would be a long, a varied, and a romantic one. Volumes have been written on the subject, and others no doubt will yet see the light. For there is this peculiarity about precious stones, that, as they are practically imperishable, their history is cumulative and in some cases, perhaps, partly legendary. Most of the great diamonds of antiquity must have hailed from India. About the origin, identity, and ultimate fate of the greatest of all, known as the *Great Mogul*, there is a good deal of obscurity and uncertainty. Tavernier gives a minute description of the diamonds of Aurangzeb, whose jewels he was permitted to weigh and inspect. " The first stone," he wrote, " that Akel-Kau placed in my hands was a great diamond, cut as a rose, very high on one side. It had a slight notch on one of its edges, and a small flaw within. It was of the first water, and weighed 280 carats." When it was brought from the Colore Mine near Golconda, Tavernier tells us, it weighed 787½ carats, but had several flaws. Small wonder that Borghis, the Venetian, got into trouble over the cutting of it. Tavernier subsequently sketched this stone as resembling a bisected egg, and Dieulafait identifies it as the *Koh-i-Noor*. The Mogul Baber (1526), on the other hand, mentions a great diamond which he obtained at Agra, weighing

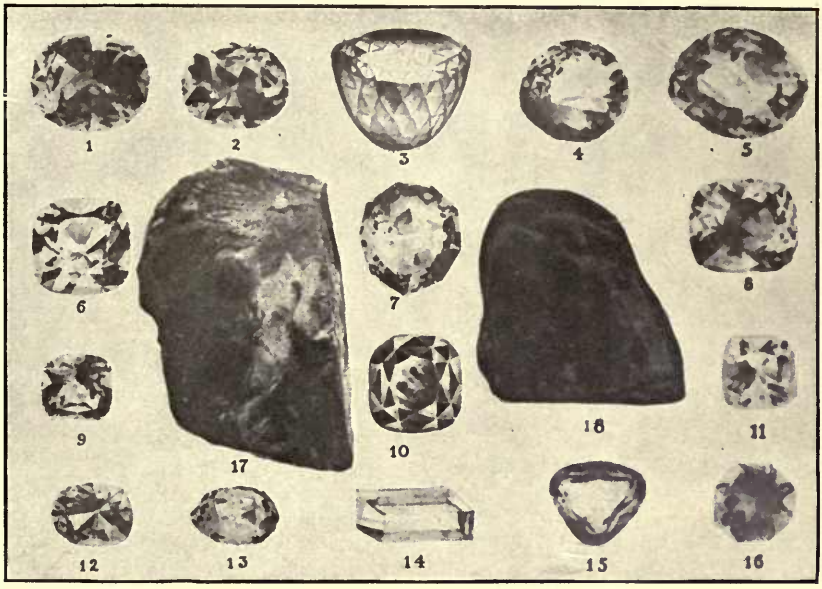
320 *ratis*, equivalent to 187 carats, and which other writers have claimed to be the *Koh-i-Noor*.

The *Koh-i-Noor*, or "mountain of light," is one of the most famous diamonds in history, but its origin is obscure. According to a Hindu legend it was worn by one of the heroes of the Mahabharata; but coming down to more historic times, it is said to have been in the possession of the Rajahs of Malwa and later of the Sultans of Delhi. Nadir Shah, on occupying Delhi in 1739, compelled Mohammed Shah, the great-grandson of Aurangzeb, who wore the diamond in his turban, to exchange turbans with him—at least so the story goes. We next find the *Koh-i-Noor* the property of Ahmed Shah of Kabul, whose successor, Shah Sujah, wore the jewel on his arm when he was driven from Kabul and became the prisoner of Runjet Sing. After that it remained in the Lahore treasury until the British annexation of the Punjab in 1849. The contents of the treasury were confiscated by the East India Company, and the *Koh-i-Noor* was presented by the company to Queen Victoria.

When this remarkable stone was brought to England it weighed 186$\frac{1}{16}$ carats and was valued at about £140,000. It was placed on view at the Great Exhibition of 1851, but as it was merely superficially cut and was disfigured by several flaws, it was decided to recut it. The operation was begun on July 16, 1852—the Duke of Wellington placing it on the cutting-mill—and was finished by the Dutch workmen on September 7, thus occupying thirty-eight days of twelve hours each. Though much reduced in weight the *Koh-i-Noor* was vastly improved in brilliance, and still remains the most historic and one of the finest gems in the British Crown.

Among the many large diamonds included in the Russian Crown jewels is the famous *Orloff* diamond,

Univ. of California



A Group of Historic Diamonds.

1. Koh-i-noor (after 2nd cutting), 106 carats.
2. Loterie d'Angleterre, 49 carats.
3. Nizam of Hyderabad, 279 carats.
4. Orloff, 194 carats.
5. Koh-i-noor (after 1st cutting), 279 carats.
6. Regent or Pitt, 137 carats.
7. Duke of Tuscany, 133 carats.
8. Star of the South, 124 carats.
9. Pole Star, 40 carats.
10. Tiffany, yellow, 125 carats.
11. Hope, blue diamond, 44 carats.
12. Sancy, 53 carats.
13. Empress Eugenie, 51 carats.
14. Shah, 86 carats.
15. Nassak, 79 carats
16. Pasha of Egypt, 40 carats.
17. Cullinan, 3,025 carats.
18. Excelsior, Jagersfontein, 969 carats.

CAUTION
DAN 95

also, like the *Koh-i-Noor*, of Indian origin. It is of a yellowish tinge, a unique semi-oval shape, and weighs 194¾ carats. We are told that it formed one of the eyes of an idol in a Brahmin temple, from which, in the early part of the eighteenth century, it was stolen by a French soldier. He fled to Madras, where he sold the looted gem to an English naval officer for £2,000. Those were the days of large profits and quick returns. The diamond was taken to England, where it was disposed of for £12,000 to a Jewish merchant. It was afterwards bought by Prince Orloff on behalf of Catherine II. for £90,000. The theory has been put forward by some historians that the *Orloff* and the *Koh-i-Noor* are both fragments of the mysterious *Great Mogul.*

Another of the world's most famous and historic diamonds is the *Regent* or *Pitt.* The rough stone was found in the mine of Parteal, south of Golconda, and weighed 410 carats. In the cutting, which occupied two years and cost £5,000, the stone was reduced to 137 carats, but the finished brilliant is considered matchless, and perfect of its kind. There are two versions of the later history of this stone. One is that it was purchased at Madras by the grandfather of the first Earl of Chatham for the sum of £12,500, and in the year 1717 was sold for £135,000 to the Duke of Orleans, then Regent of France during the minority of Louis XV. The other and more picturesque version credits the *Regent* diamond with many more interesting vicissitudes. According to Saint-Simon the stone was stolen by an employé at the diamond mines, who escaped to Europe with it. He tried to dispose of it in England, but, failing to do so, went to Paris and showed it to the notorious financier Law. The latter induced the Duke of Orleans to purchase the stone, and after that it became identified with the fortunes of France. In the days that followed the fall of Louis XVI. this famous

diamond, carefully guarded by gendarmes, was exhibited to the people of Paris. Pawned by Napoleon, and, after being stolen and recovered, mounted in his State sword, the stone passed through many vicissitudes both before and after glittering in the crown of Napoleon III.

Of other great Indian stones one of the most notable is the *Nizam*, a large diamond of 277 carats, now in the possession of the Nizam of Hyderabad. Then there is the *Great Table*, a flat oblong stone shown to Tavernier at Golconda in 1642, which is supposed to be identical with the *Darya-i-Nur*, also a rectangular stone, now among the jewels of the Shah of Persia. The *Sancy*, although comparatively small, weighing only $53\frac{3}{4}$ carats, has a long and varied history. It changed hands frequently, and has been the property of such distinguished people as Charles the Bold, Queen Elizabeth, Henrietta Maria, Cardinal Mazarin, and Louis XIV. of France. It shared the fate of the *Regent* in being stolen during the French Revolution. Subsequently it became the property successively of the King of Spain, Prince Demidoff, and an Indian prince.

Brazil has not been particularly prolific of very large diamonds, and of those which have been produced most have been acquired for the Kings of Portugal. Of these, however, few details have been published. The most famous of Brazilian gems is that known as the *Star of the South*. This remarkable diamond is said to have been found by a poor negress in the mines of Bagagem in the year 1853. The uncut stone weighed $254\frac{1}{2}$ carats and was valued at £40,000. When cut it was found to be a flawless gem, of a lovely rose tint, and was sold to the Gaekwar of Baroda for £80,000.

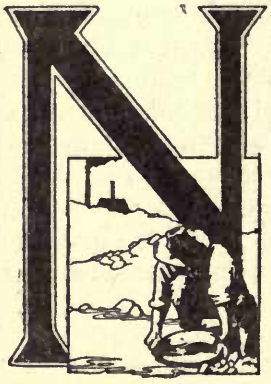
Included in the immense output of the South African diamond mines have been a number of large and valuable stones. In addition to the *Star of South*

Africa, already mentioned, the *Stewart*, an even finer diamond, of 120 carats when cut, was also found at the River Diggings. Then there was the *Victoria*, a fine stone of 180 carats (cut) which was sold to the Nizam of Hyderabad for £400,000; the Porter Rhodes, a jewel of 150 carats; and the Tiffany, a magnificent orange-yellow brilliant of 125½ carats. Some of the largest as well as the finest stones hail from the Jagersfontein Mine. The *Jubilee*, found in 1895, weighed 640 carats in the rough and 239 carats when cut. The *Excelsior* was discovered in 1893 by a native when engaged in loading a truck. It was of great size, weighing uncut 971 carats, and was cut into ten stones varying from 13 to 68 carats. The *Excelsior* was in fact the largest diamond known until 1905, when the *Cullinan* was found. South African stones have not acquired the historic value and associations of the older Indian ones, but in every other respect they are their peers and include some of the largest and finest gems the world has ever seen. But the chiefest glory of South Africa is the incomparable *Cullinan*, which may be said to mark the culminating point of the romantic story of the diamond mines of the world.

SILVER

CHAPTER X

SHEKELS OF SILVER



EXT to gold, silver is the most valuable and widely distributed of the precious metals known in history, and has been used for ornaments, jewellery, coinage, and articles of value from time immemorial. In colour it is proverbially white and shining, and the etymology of the word probably refers to these qualities. The Latin word *argentum* is cognate with the Greek ἄργυρος (silver), which in turn is derived from ἀργός (shining). Further, the Hebrew name (*Kheseſ*) is connected with the root *khasaſ*, meaning "to be pale." As with gold, the word silver is used symbolically. Those wizards of the Middle Ages, the alchemists, adopting the classic parallel, called silver Luna or Diana, and signified it by the familiar symbol of the crescent moon.

Silver is slightly harder than gold, but is neither so malleable, so ductile, nor so heavy. It is not acted upon by pure air, but it is tarnished in towns because of the sulphuretted hydrogen present in the atmo-

sphere. Silver is very widely distributed throughout the world, both on land and, in minute quantities, in the sea. Among minerals it occurs in its free metallic or native state, often in twisted wire-like forms, sometimes in crystals, but more frequently in laminated or amorphous masses varying from 50 to 800 lb. in weight. Silver is, however, most commonly found in a mineralized form, as ore, in which state it is found associated with gold, copper, lead, arsenic, antimony, bromine, iodine, sulphur, and various acids. The two principal of the numerous ores of silver are silver glance, or sulphide of silver, and horn silver, or chloride of silver. The first-named, which is sometimes called argentite, has a metallic lustre and is of a dark grey colour. It is one of the richest and most abundant of silver ores, being found in Saxony, Bohemia, Hungary, and Mexico. A steel-grey sulphide of silver and copper called stromeyerite is found in Silesia, Peru, Chile, Siberia, Arizona, and Colorado. Chloride of silver contains about 75 per cent. of silver. It is grey in colour and horny or waxy in appearance. When being roasted or smelted it emits acrid fumes of chlorine. Silver chloride is the commonest ore in Mexican and South American mines. A great deal of the world's silver is extracted from silver-bearing galena or lead ore, in which a small amount of sulphide of silver is almost invariably present with that of lead.

From the metallurgist's point of view, silver ores may be divided into two great groups, namely, pure silver ores and argentiferous ores; the former being a mineral in which silver is the only metal present, and the latter, ores which contain an admixture of other metals, usually gold, copper, lead, or iron.

As regards the comparative antiquity of the knowledge and use of gold and silver, this is an open question which will in all probability never be satisfactorily

answered. We read in the Scriptures * that Abraham weighed to Ephron the Hittite "four hundred shekels of silver, current money with the merchant," for the purchase of the field of Machpelah, where Sarah was buried. The date of this transaction is fixed by Biblical chronologists at about the nineteenth century before the Christian era. Although this may be considered as only an approximation, still it is admissible as evidence to show the antiquity of the use of a silver currency.

Silver itself was undoubtedly known at an even more remote period. Diodorus was one of the earliest writers to mention its discovery in the Iberian peninsula. He relates that, some shepherds having set fire to a forest in the Pyrenees, streams of molten silver flowed out of the calcined soil. The metal was bought for a trifle by the Phœnicians from the natives, who were ignorant of its value. Homer describes the shields and helmets of his heroes as inlaid with silver, and the Babylonian, Assyrian, and Persian monarchs imposed large tributes of silver on the conquered nations of Asia. There were silver-mines in ancient times in Eastern Siberia. Gmelin, writing of the remains of the old smelting works attached, remarked that the silver had all been extracted from the ore, but the lead was left to mingle with the scoriæ.

Silver has almost invariably been considered to be of less value than gold. In the time of Menes—which has been placed at from the thirty-ninth to the thirty-seventh century before Christ—the value of gold in Egypt was fixed at two and a half times that of silver. Ever since that remote period the tendency has been for the ratio to widen, that is for the difference in value between gold and silver to become greater. A notable exception is recorded in a fragment of the

* Genesis xxiii. 15.

works of Agatharchides—a Greek geographer who lived in the time of Ptolemy VI., Philometer, King of Egypt (181–145 B.C.). There it is stated that at one time the value of silver in ancient Arabia was tenfold that of gold.* No date is assigned to the period referred to, but it may safely be assumed that it was long anterior to the writer's own times. An additional proof of this is to be found in the fact that in the seventh century B.C. the ratio had reverted to the more normal one of 1 gold = 13·33 silver—our knowledge of which is derived from the cuneiform inscription at Nineveh, attributed to the year 708 B.C. Still, although the ratio of value has fluctuated from time to time, the value of silver has almost always been estimated as less than that of gold.

The silver-mines of Greece were among the most important known to the ancients. The principal were those at Laurium or Laurion in Attica. Themistocles persuaded the Athenians to devote the revenues of these mines, which were the property of the State, to the building of ships, and so laid the foundation of Athenian naval greatness, which culminated in the victory of Salamis. The mines were usually farmed out for a certain fixed sum plus a percentage on the profits of working. Slave labour was exclusively employed, and in order to prevent their escape the slaves were worked in companies and were kept under constant surveillance. As was not unnatural under the circumstances, the helots or slaves, exasperated by the enforced labour and the many hardships of their condition, frequently rose in rebellion. Their harsh treatment forms one of the least pleasing chapters in the history of Hellenic civilization. The ancient workings, consisting of shafts and galleries for excavating the

* Jacob, Vol. I. p. 97.

ore, may still be seen, as also the pans and other devices for extracting the silver from the ore, and separating it from the lead which was also present. Towards the end of the fifth century B.C. the output began to diminish, but the mines continued to be worked. Pausanias, writing about 475 B.C., refers to the mines as abandoned before his time, while Strabo mentions that the tailings were being worked over. It is an interesting fact that the mines are still worked by French and Greek companies for lead, and that the refuse, re-treated by modern methods, has yielded a profitable return.

The greater portion of the silver of antiquity was derived from the mines of Iberia, which, as we know, were worked by the Carthaginians from about 480 to 206 B.C. Mining was reduced by them to a regular system, and the slave labour employed enabled them to secure a very large output from the mines. The famous silver-mine of Bebulo, which furnished Hannibal with the sinews of war for his campaign in Italy, was situated at Guadalcanal at the foot of the Sierra Morena. Pliny wrote of it: "It is very singular that the mines begun by Hannibal still exist and retain the original names given by persons who first explored them. One is still called Bebulo, from the discoverer, which formerly supplied Hannibal with 300 lb. weight of silver daily." Pliny goes on to inform us that the mine was worked by means of passages under the mountain, one and a half miles in length, in which the labourers, standing in water, worked night and day by lamplight to drain off the water, which at length formed a large river. Judging from modern surveys of the mine, the water, which was only partially drained by a costly subterranean tunnel mentioned by Pliny, gradually overflowed the whole of the workings, but whether the mine was abandoned on that account, or because it had been exhausted of its mineral treasures, is not clear.

The produce of the Iberian mines was taken to Carthage. Thence the surplus was disposed of in Rome and other Italian cities, and was even sent as far as India, where on account of the scarcity of silver that metal could always be exchanged for gold with advantage. After the formal adoption of silver by the Romans as part of their monetary system in 267 B.C., they soon found that export, hoarding, clipping, and the ordinary abrasion of everyday use combined to make a steady drain on their stock of silver. Consequently larger and more regular supplies were imperatively required. There is little doubt that this demand, together with the desire of the Romans to secure the means to extend their commerce with the Orient, eventually led to the second Punic War. The Romans were successful in wresting Iberia from the Carthaginians, and caused the mines to be worked with unflagging energy. First the remnants of the native Iberian races and the Carthaginian captives were sent to toil in the mines. Then, their ranks being thinned by disease and death owing to their arduous labours, condemned criminals were sent from Rome, and latterly even legionary soldiers.

According to Polybius, as quoted by Strabo, the silver mines near New Carthage, the modern Cartagena, were extremely productive. They were situated about 20 furlongs from the city and were scattered over an area of some 40 furlongs in circumference.

Strabo describes the treatment of the ore as consisting of roasting followed by washing through sieves. This operation was repeated five times, and the residue was fused with lead and cupelled or skimmed, leaving pure silver. In these mines no fewer than 40,000 men were constantly employed, who at that time produced an output of from 20,000 to 25,000 drachmas. If the drachma be taken at the average value of $8\frac{3}{4}d.$, the

product of the mines would be over £900 per diem. But this sum divided among the 40,000 slaves indicates an average output of only $5\frac{3}{4}d.$ per head in value, or about the pay of a Roman foot soldier of the period (which was supplemented by spoil). Such being the case, the product of these mines would barely suffice to purchase food for the wretched slaves condemned to work in them, and when the cost of supervision, implements, timber, and transport was added, it will be seen that, rich as the Iberian mines were, they form an early instance of unprofitable speculation in mining.

In addition to the silver-mines of the Iberian peninsula the Romans are known to have worked the Rothausberg and other mines in Austria and the Tyrol. But after the fall of Roman civilization, as we have seen in the case of gold, little or no mining was carried on in Europe for several centuries, at least outside the confines of Saracenic Spain.

Following on the Moorish conquest of Spain in the eighth century, the Spanish mines were among the first in mediæval Europe to be reopened. The ancient silver-mines, which were thought to have been exhausted, were made to yield afresh by thorough and skilful working, and the Iberian mines once again began to furnish the world's chief supplies of the precious metals. Quicksilver was also mined and exported to Constantinople, probably for use in the silver mines of the Hedjaz (Midian), which the Arabs had reopened after they had been abandoned by the Romans.* In all probability, too, the Saracens made many new discoveries during the seven or eight centuries they were masters of the Peninsula. They are believed to have worked the silver-mine of Zalamea in Andalusia, that of Constantina near Cazalla, and

* Captain Burton's "Land of Midian."

perhaps also that of Guadalcanal, as well as the ancient Roman mines on the northern slopes of the Pyrenees. In many of the mines Christian slaves and captives were employed.

Apart from Saracenic Spain the greater proportion of the silver supply of Europe during the Middle Ages was derived from the mines of south-eastern Germany. One of the earliest to be discovered and worked was the Rammelsberg, near Goslar in the Hartz Mountains, which was opened up about the year 968 and largely contributed to the wealth of the Emperor Otho. The story goes that the discovery of the Rammelsberg deposit was made by a hunter of the name of Ramm. In an interval of the chase Ramm had fastened his horse to a tree, and the animal, as horses do, had stamped and scraped the soil with its hoof, thus laying bare the precious metal, specimens of which were sent to the Emperor Otho. It is said that the mine was abandoned in the middle of the fourteenth century, but working was resumed a century later and continued right up to modern times. This mine has therefore been operated with but one interval for over nine centuries.

There were, too, other silver-mines of importance in mediæval Europe, some of which were opened up even earlier than the Rammelsberg. Those near Schemnitz, consisting of silver and lead veins, were first worked in the seventh century, were closed in 1442, and reopened in the seventeenth century. The mines of Kremnitz, which yielded both silver and gold, were opened about the eighth century. The Rothausberg Mine, which, as we have seen, was originally worked by the Romans, was reopened also during the eighth century. We find this mine referred to in the year 1378, when Archbishop Pilgrim leased it for a rent of £320. In the Hautes-Alpes the mines of L'Argentière,

which had also been worked by the ubiquitous and indefatigable Romans, were reopened previous to or during the twelfth century. The mines of Neusohl in Lower Hungary, which were operated in veins of argentiferous copper, date from about the thirteenth century, and those of Schmölnitz from a later period.

Silver was, according to popular tradition, first found in Saxony about the tenth century, when some carriers from Halle on their way to Bohemia observed a shining, white, metallic substance in the wheel-tracks made by their carts. This metal turned out to be a specimen of silver-bearing lead ore. But if any mines were opened up in this district the very site of them is now lost, the reputed spot being occupied by cornfields and vineyards. Those Saxon mines of which we have any authentic record date from a later period. The Schneeberg for the space of thirty years—from 1320 to 1350—produced about 100,000 lb. weight of silver per annum.

The Salzburg mines in Austria were productive of silver as well as gold in the fourteenth and sixteenth centuries, and the Altenburg in Hungary during the fifteenth. The Schellgadin Mine was so rich in silver during the sixteenth century that it was called "The Throne of Plutus."

With the exception of this comparatively limited number of mines in Spain, Saxony, Bohemia, and Hungary, it may be said that mining was practically at a standstill during those dark days of the turbulent early Middle Ages. Europe was split up into the armed camps of rival feudatories constantly engaged in predatory warfare, during which the stocks of precious metals frequently changed hands. The practical discontinuance of mining was a natural corollary of the social unrest and the general absence of commercial

security. A continuous shrinkage in the world's stock of gold and silver was an inevitable result.

The quantity of gold and silver money in the Roman Empire at the death of Augustus (A.D. 14) was computed by Jacob at £358,000,000 sterling, but this estimate is now considered to be very much in excess of the actual amount. However that may have been, it is generally agreed that by the beginning of the ninth century the world's stock had decreased to between £30,000,000 and £40,000,000 sterling. After that the output of the European mines apparently sufficed to make good the loss by hoarding, abrasion, and export; the stock of money was thus kept at the above level down to the discovery of America in 1492.

As to the relative proportions of gold and silver in the world's stock of precious metals, it is difficult to give the precise amounts for any period prior to the discovery of America. But as the stock of the precious metals has always been an important factor in determining the ratio of value between gold and silver, a consideration of the variations in that ratio will afford some idea of the fluctuations in the world's holding of bullion.

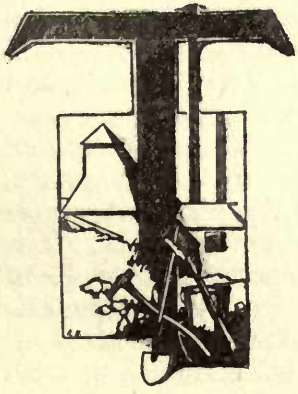
We know that the payment of the Egyptian tribute to Darius (500 B.C.) was based on the ratio of 1 gold = 13 silver.* From this period silver fell in value, and the ratio widened until it stood in Greece at 1 gold = 14 to 15 silver, and this probably held good throughout Levantine Europe and Asia Minor. From that time onwards, however, up to the discovery of America, gold fell in value, or, conversely, silver appreciated, until in 1492 the ratio stood at about 11 all over Europe. Briefly, then, and without entering further into the vexed question of the relations between the

* Herodotus, III. 95.

ratio and stocks of bullion, it may be said that in nineteen centuries silver had increased in value from one-fourteenth or one-fifteenth that of gold to one-eleventh. Apparently the stock was practically stationary, while the demand for silver in commerce and the arts was expanding immensely. Fortunately the mines of the New World promised to supply the demand and so to play an important part in the inauguration of a new era.

CHAPTER XI

ARGENT AMERICA



THAT the history of the discovery of the New World was closely and even intimately associated with the story of the search for the precious metals, will be evident to every student of the chronicles of the period. When the existence of a whole vast new continent in the West became an accepted fact, even this wonderful reality was eclipsed, in the minds and imaginations of Europeans in general and Spaniards in particular, by the richly embroidered tales of the marvellous wealth of its resources, more especially in the precious metals. Exploitation quickly followed discovery, and it is a significant fact that the former was prosecuted with the most energy and thoroughness wherever the precious metals were thought to be present.

Hispaniola, Cuba, and Mexico were, as we have seen, all ransacked for gold. Silver at first occupied merely a minor position in the regard of the Conquistadores, and it was only in the absence of gold and the presence of silver in large quantities that they attached much importance to the white metal. But soon the repeated finds of veins of silver which for richness

and productivity excelled anything hitherto known, attracted the attention of the Spaniards, and they lost no time in setting the Indians to work at the mining of the silver ores.

The Spanish conquerors first found silver in Mexico. The Aztecs were thought to be ignorant of the art of obtaining silver from the ore, as few silver ornaments and no silver coins were to be found. On the other hand, a modern visitor to the silver-mines of Santa Eulalia, twenty miles east of the city of Chihuahua, gives evidence which points to the extreme antiquity of some of the workings. In a chamber from which it is evident that a great "bonanza" vein of ore had been extracted, a huge stalactite may be seen, measuring 60 feet long and 20 feet thick. There were, too, other indications of the antiquity of these mines, which it is supposed were worked by the Aztecs, or perhaps even by the Toltecs, an earlier race. The formation of new ore upon the otherwise clean walls of the chamber may also be detected. Similar phenomena have been noticed in others of the older Mexican mines, and they are interesting in connection with inquiries concerning the formation of ore deposits.

Of the silver deposits of Mexico the lodes of Tasco and Pachuca were among the first to be opened up by the Spaniards, soon after the conquest. The mines of Zacatecas, though distant four hundred miles from the capital, commenced working in 1548, only twenty-eight years after the death of Montezuma. From that time onwards Mexico has been one of the most remarkable silver-producing countries the world has known.

The great mining district of Mexico runs from north-west to south-east, following the direction of the Sierra Madre Cordillera from Sonora to the south of Oaxaca, a distance of 1,600 miles. The richest mines

have been located on the western slope of the Cordillera. Apart from Sinaloa and Sonora, which are now known to be rich in deposits of the precious metals, nearly all the historical mines are situated on the south central plateau at elevations varying from 5,500 to 9,500 feet. A line drawn from the capital to Guanajuato and thence onwards to the mining town of Guadalupe y Calvo in Chihuahua and southwards to Oaxaca, will intersect probably the richest known argentiferous region in the whole world. The central group of mines in the three mining districts of Guanajuato, Zacatecas, and Catorze (San Luis Potosi) have yielded more than half the silver hitherto found in Mexico.

Muleteers travelling from the city of Mexico to Zacatecas are said to have found the silver lode at Guanajuato. The Sierra de Santa Rosa, a range of mountains the slopes of which are partly arid and partly covered with evergreen oak, stretches across the centre of the province of Guanajuato. Along the southern slopes of this range runs the famous *Veta Madre* or mother lode, one of the richest silver veins in the world. This remarkable lode traverses the district for eight miles, and varies from 120 to 135 feet in thickness. It is not, however, productive throughout its entire length; the ore occurs in bunches with intervening spaces of barren rock.

In addition to the mines of Pachuca, those of Moran and Real del Monte began to be worked soon after the conquest of Mexico by the Spaniards. The Veta de la Biscayna, the chief vein of the district, yielded an immense output from the sixteenth to the beginning of the eighteenth century, when most of the workings were flooded. The owners constructed an adit or gallery over a mile and a third in length to drain them. The great cost of this was amply repaid, for silver to the value of over £3,000,000 sterling was

extracted from the mine. About the year 1774 the profits of the Biscayna began to diminish. The workings had reached a level of 300 feet below that of the adit, and although ore was still plentiful, water poured into the mine at such a rate that 28 *baritels*—primitive sets of appliances for raising water in skin bags—each requiring forty horses, were incapable of coping with it.

One of the richest of Mexican silver-mines—that of Valenciana—had its origin in humble and romantic circumstances. A young Spaniard named Obregon began to work the lode about the year 1760, with the assistance of some friends who advanced him the necessary capital. Six years later the workings had reached a depth of 240 feet, and still the output did not even cover the working expenses. But Obregon clung with dogged pertinacity to the hazardous enterprise on which he had staked all he possessed. His faith in the future of the mine was unwavering, and was justified by events. In 1767 he entered into partnership with one Otero, a shopkeeper. Soon the tide turned, the produce of the mine began to increase, at first slowly, and then by leaps and bounds, and by the year 1771 it was yielding enormous masses of sulphuret of silver. From that time till 1804, when he left Mexico, Humboldt tells us that the Valenciana mine never produced less than £560,000 worth of silver annually, and that the net profits of the partners amounted in some years to £240,000. Señor Obregon was, too, ennobled under the title of Conde de la Valenciana, and within ten years of opening out his mine he had the satisfaction of seeing a thriving mining community of 8,000 souls growing up around it.

Previous to 1770, the now populous district of Alamos de Catorce, in the State of San Luis Potosi, was an almost uninhabited wilderness. In that year a free negro named Milagros, who was an itinerant

musician, having lost his way, had to spend the night in the forest. He lighted a fire, and next morning he found a few globules of melted silver among the ashes. A more extended search revealed the outcrop of a rich vein of silver ore. Milagros lost no time in establishing the right of property which he derived from his discovery, and, opening up the mine called after himself, became in a few years a wealthy man.

Silver-mining, which, as we have seen, was the best known and most productive industry in Mexico, and the chief occupation of European residents during the three centuries of Spanish rule, received, in common with gold-mining and most other commercial undertakings, a serious setback during the years of the Spanish-American revolution. During the years immediately preceding the revolt, say from 1781 to 1800, Mexico yielded no less than two-thirds of the world's total production. With the outbreak of the rebellion, however, the output immediately fell off, the mines were abandoned, and the plant, machinery, and workings fell into ruin and decay. It was only in the " twenties " of the nineteenth century, with the introduction of European capital, that the mines resumed anything like their former prosperity.

An English company undertook the workings of the mines of Real del Monte, and after expending over $15,000,000 to secure a total output valued at $10,000,000, was dissolved in 1848. A Mexican company took over the mines, and under British management a new era of prosperity was inaugurated. The great Rosario vein was almost immediately struck, and with such good results that in the year 1867 the mines yielded a profit of $1,000,000. At that time a *conducta* or escort of one hundred and fifty armed men conveyed the silver fortnightly, in bars of 70 lb. locked in iron safes, to the capital.

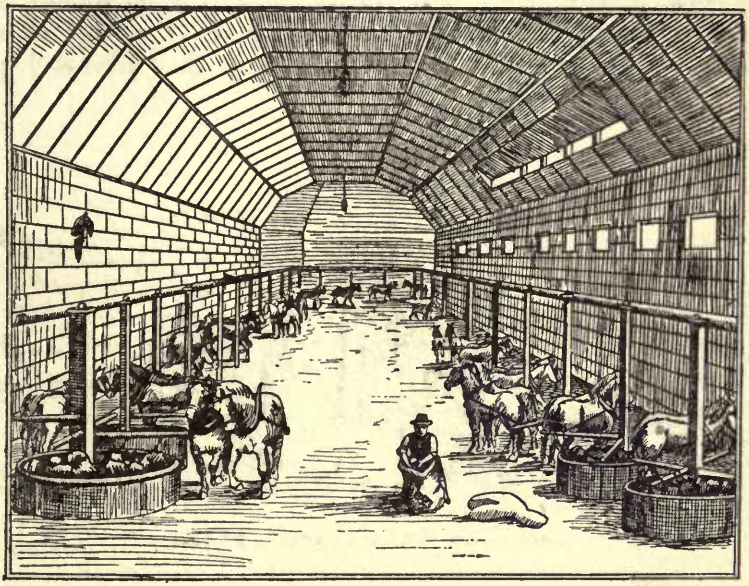
The old Mexican mines were worked on very haphazard and unscientific lines. The lodes were worked with little foresight or regard for the levels and communications necessary for the economical transport of the ore. Even winding was impracticable, so irregular were some of the workings. Most of the ore had to be conveyed to the surface on the backs of Indians, who climbed the many long steep ladders with heavy loads on their backs in a way that astonished even such an experienced traveller as Humboldt.

As with other metals, the separation of silver from its ores is effected in various ways, according to whether they are of a "free-milling" or a refractory nature. In the former event they are amenable to amalgamation, that well-known quality of quicksilver by which it forms an amalgam with the precious metal present in finely pulverized ore. Most of the Mexican silver has been extracted from the ores by a modification of this method called the Mexican or Patio process.

This process was devised by Bartholome Medina, a native of the Mexican town of Pachuca, in 1557. It shows a good working knowledge of chemical reactions, and although it has long been improved upon and surpassed by modern methods, it is still carried on in Mexico and some parts of South America. And it is found to be, not only fairly effective, but probably best adapted to local conditions where labour is cheap and fuel and water-power are scarce.

In the old-fashioned Mexican mines the ore, on being brought to the surface, is taken in hand by the *pepenadores*, men and women who sort the ore and break the larger pieces with hammers and prepare them for the *molinos* or stamping-mills. These latter are usually of the old Cornish type, and are worked either by mules or, where water-power is available, by a water-wheel. The lifters or pestles are made of wood,

shod with iron, and weigh about 200 lb. each. The crushed ore from the stamping-mill is taken to be ground still finer in the *arrastras* or crushing mills. These latter each consist of a vertical shaft connected with two cross bars to which are fixed the grinding stones. The *arrastras* are usually about 12 feet in diameter, and are made to revolve by mules walking



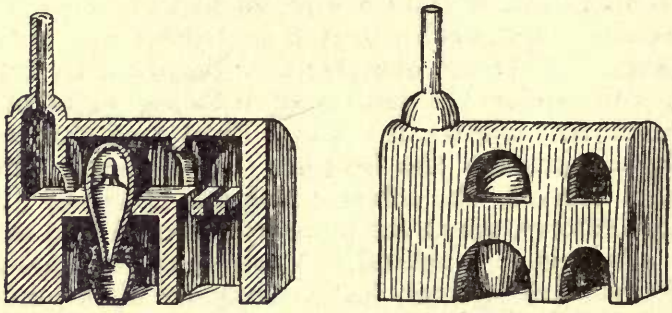
GRINDING MILLS IN SHED.

in a circle. The grinding stones as well as the pavement are made of porphyry. Our illustration shows a number of them arranged in a gallery or shed. Water is added to the crushed ore, and the resultant slime is led into shallow tanks, where it remains exposed to the sun until evaporation renders it of the consistency of thick mud.

This slime, or *lama*, as it is called, is then transferred

Of late years the cyanide process, so well known in connection with gold-mines, has been applied to the treatment of silver ores in Mexico, and has proved very successful. The method as applied to silver does not differ materially from its application to gold, but the length of time occupied in treatment is longer, owing to the slower rate of solution of silver in the cyanide, a stronger solution of which has to be utilized.

Mexico is still one of the world's greatest silver-producing countries. Its output of 73,838,066 oz. in 1905 was a record for any single nation. Of the huge number of 23,191 mining properties registered in 1906,



FURNACE FOR REDUCING SILVER, CHILE.

five-sixths were described as mines producing silver, or in which silver was the principal product. There were no fewer than 5,461 mines recorded as producing silver alone.

Ever since the invasion and conquest of Peru by Pizarro and his fellow-adventurers, that country has been famous for its silver-mines. But even previous to the advent of the Spaniards, silver ore was procured by the Incas in open workings. They smelted it in portable furnaces of clay, which were pierced with a great number of holes. These furnaces were placed in an exposed position on the mountain-side, filled with alter-

nate layers of ore and charcoal, and then lighted. The mountain breezes provided the forced draught, and the result was a crudely smelted argentiferous mass, which the natives resmelted and refined in their huts by means of a species of blow-pipe. Immediately after the fall of Inca rule the Andean slopes and valleys were thoroughly explored by the Spanish invaders, and with the help of the Indians—who under the system of enforced labour were practically enslaved—thousands of mines were opened up, many doomed to failure, some few to become famous.

The great mineral wealth of Peru lies in the lofty and mountainous Andean region. An immense number of silver veins have been found, but, as is not uncommonly the case when Nature bestows great riches on humanity, she hides them in almost inaccessible places. Most of the Peruvian silver-mines lie at an altitude of over 12,000 feet above sea-level. The principal silver-producing areas in these high-lying valleys and plateaux are those of Cerro de Pasco and Huallanca in central Peru, Salpo and Hualgayoc in the north, and Lucanas and Puno in the south. The most famous of all the old Peruvian mines—those of Potosi—are now of course included in the modern republic of Bolivia.

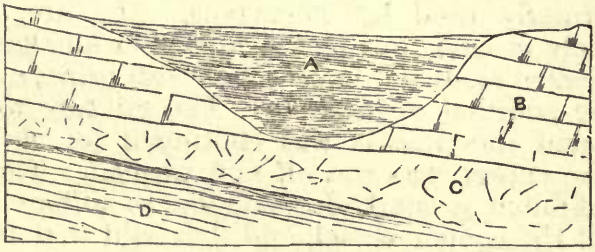
The principal silver-mines of Peru proper are those grouped about Pasco, on the high plateau which lies between the Cordilleras and the Andes at an altitude of about 13,000 feet. Silver is said to have been discovered about the year 1630 by an Indian shepherd who, after lighting a fire, found traces of the white metal among the ashes. The outcrop he had accidentally lighted upon was the forerunner of many valuable lodes, chief of which are the Veta de Colquirica and the Veta de Pariarica. The town of Pasco soon sprang up, and has ever since been a centre of mining activity. The Veta de Colquirica runs north and south, and has an average

thickness of 400 feet. The Pariarica lode runs in a W.N.W. to E.S.E. direction and crosses the other main lode under the market place of the town of Pasco. Many of the entrances to the mines were situated in the town itself, and as they were carelessly worked, the necessary timbering and supports being frequently neglected, subsidences were common. The Cerro de Pasco district, with its 342 silver-mines, is credited with a total production between the years 1784 and 1889 of £40,000,000, and many of the mines are still productive, the yield in 1906 being £972,958. About Cerro de Pasco is found a curious ore called *cascajo*, which has no metallic brightness, probably on account of the oxide of iron present, but which is rich in silver and also in copper ores. Copper-mining is now a most important industry in this district.

Many romantic stories are told of the silver-mines of Peru. Each find had its tale, more or less embellished by the love of the picturesque shared by Spaniard and native alike, and the buried treasure might well form a powerful *motif* in a thrilling drama. Thus there is the story of Don José Salcedo, a Spaniard who was poor, but not too proud to fall in love with, and even to marry, an Indian maiden. The girl's mother revealed to him the whereabouts of a rich lode of silver. Salcedo opened up the vein and the mine proved very productive and remunerative. His new-found wealth excited the cupidity of Count Lemos the Viceroy, who sought to obtain possession of the mine. The latter made much of Salcedo's popularity amongst the Indians, and accused him of fomenting rebellion among them. The unfortunate mine-owner was cast into prison, was ultimately condemned to death, and, notwithstanding his petition to have his case submitted to the high court of justice at Madrid, was summarily hanged. So incensed were his faithful Indian friends at this judicial murder that they

destroyed the works of the mine, and so carefully concealed the entrance that its exact location has remained unknown ever since. Such is the story told in some of the Peruvian valleys, and the reader must admit that the element of poetic justice meted out to the Viceroy renders the story one that at least deserves to be true.

Other notable Peruvian silver-mines were those at Caxamarca, and Hualgayoc. The Cerro de San Fernando de Hualgayoc, which lies 14 leagues from the town of Caxamarca, is an isolated mountain traversed by innumerable veins of silver. Its steep sides are pierced, not only by the natural openings through which the



SILVER ORE STRATA, STA. ROSA, PERU.

blue sky can be seen, but by several hundred galleries for the extraction of ore. During the first thirty years after the discovery of the mines in 1771, they yielded silver of the value of $30,000,000, and they are stil productive.

In the vicinity of Aquique there are many famous mines, notably those at Hucantajaya, Santa Rosa, and Hunataca. At Hucantajaya there are several silver lodes which are nearly vertical and radiate from the common centre of the hill Aquique. The argentiferous beds at the Santa Rosa Mine resemble those at Kongsberg, Norway, and were at first most productive, though latterly they have fallen off in value.

Silver in Peru is generally found in the form of red oxides (called locally *rosicler*), sulphides, and mixed with lead. Modern machinery is not much used in the up-country mines, and many are practically unworkable for want of pumps.

Some few years ago, when the official list of mines was issued, there were nearly 10,000 claims listed, and out of these nearly 1,200 were being worked by 160 native and foreign companies. Labourers in the mines are recruited from the Indians and mixed native races.

The amalgamation process was first introduced into Peru about the year 1570. The *cazo* or cauldron process was a simple method of treating the silver chloride ores formerly used by Peruvians. The ore, having been finely ground, was placed in copper amalgamation vessels called *cazos* and boiled, first with brine, and then with the addition of mercury. The mixture was kept stirred and the process was continued for six hours, when the charge was run off and washed. The amalgam exhibited a marked tendency to adhere to the inside of the copper vessel, and it is said that this fact first suggested the use of copper plates in the amalgamation process as applied to gold. The Fondon process was an improvement on the *cazo*. Bars of copper were made to revolve on the bottom of the cauldron by mule or water-power, and the minute particles of copper worn off facilitated the reduction of the silver.

There are many large plants nowadays in Peru for the treatment and smelting of ores. According to recent statistics there are 24 lixiviation, 17 amalgamation, 13 smelting, and 3 concentration plants. The Cerro de Pasco Company, a large American copper-mining concern, has the largest smelting works, with a capacity of 500 tons per day, but there is also the Huaracaca smelter on the road to Pasco, which has, with concentration and amalgamation, a capacity of 100 tons per day.

The territory now comprised in the State of Bolivia was, until the Spanish-American revolution, included in and formed part of Peru. In 1825, however, the inhabitants of Upper Peru asserted their independence, and eventually the republic of Bolivia came into being. The historic "silver mountain" of Potosi now lies within its frontiers, but its ancient glories have waned and been replaced, though never surpassed, by other mines.

The discovery of silver on the slopes of the snow-capped Cerro di Potosi, in 1545, was one of the first and certainly the most famous ever made even in South America—the Silver Continent. Tradition has it that an Indian, while in pursuit of deer on the steep mountain-side, took hold of a shrub. The roots of the plant gave way, exposing to view a mass of silver. The Indian kept his secret for a time, and then shared it with another Peruvian. The pair quarrelled, and the second Indian divulged the whereabouts of the mine to his Spanish master, one Don José Villaroel, whose extraordinary success in the working of the mine soon attracted the attention of all America to the rich deposits of Potosi.

The mining camp at the foot of the Cerro, even in this remote and inaccessible region, 12,842 feet above sea-level, rapidly developed into the large town of Potosi. Supplies reached fabulous prices, as everything had to be conveyed on pack-mules over the mountains. The Cerro itself rapidly became honeycombed with mine shafts and galleries. The mountain mass is traversed by no fewer than thirty-two principal lodes, as well as by a number of smaller veins, which form a network in the older rocks of which the range is composed.

During the period of their greatest prosperity, between the years 1585 and 1606, over 15,000 Indians were employed in the mines of Potosi. In the province of Potosi alone 12,000 Indians were annually subjected

to the *meta*, a system of compulsory labour. The mortality, owing to the unaccustomed labour and the primitive and arduous working conditions, was very heavy, and particularly so among those natives drafted from the warm coast regions to work in the rarefied and chilly air of these mountain mines, some of which lay at an altitude higher than Mont Blanc. In the Munoz collection of manuscripts, relating to Peru, there is a letter written to the King of Spain by Father Domingo de Santo Thomas, and dated 1550. In the course of this epistle, the good padre gives an elaborate account of the terrible sufferings and privations of the Indios in the Potosi silver-mines. He concludes: "*Se mueren los pobres como animales sin dueño . . . los que de esto se escapan jamas buelben a sus tierras.*" * ("The poor creatures died like cattle . . . and even the few who escaped alive never reached their homes.")

Notwithstanding the sufferings of the native miners, the output of these silver-mines among the clouds never flagged. At first the native method of smelting the ore in small furnaces on the mountain-side was adopted, and early travellers among the Cordilleras wrote with enthusiasm of the striking and picturesque sight presented by the thousands of fires which blazed at nights on the serrated ridges of the Cerro di Potosi.

From 1545 to 1800 the Spanish crown tax of one-fifth upon the mineral product amounted to £32,600,000, thus showing an acknowledged output of £163,000,000 in value. The actual yield must, however, have been much in excess of this amount, as Spain was flooded with contraband silver, and there was an extensive traffic in it at the La Plata ports, whence it was sent to Brazil and Portugal. Humboldt estimates the total production of the Potosi mines for the above-

* Helps, Vol. III. p. 146 (note).

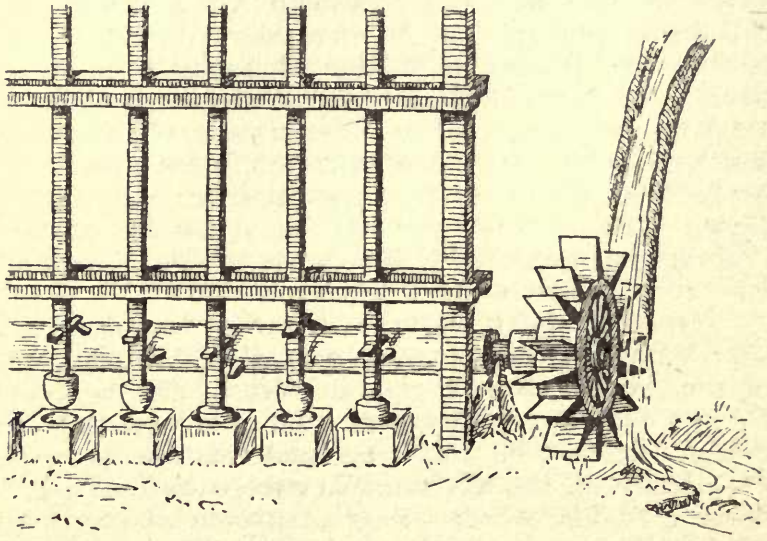
mentioned period at a valuation of £230,000,000. Later calculations place the yield up to the end of 1864 at anything between £300,000,000 and £400,000,000 sterling. The annual output at the beginning of the twentieth century had dwindled to something like 400,000 oz.

The Department of Potosi comprises the great mining region of Bolivia, the western plateau being particularly rich in silver. The Huanchaca group of mines, situated on the slopes of the eastern Cordilleras and overlooking the morasses and saline plains of the Pampa de Empeza, now produce the largest output of silver in Bolivia. The Pulacayo Mine, belonging to this group, and lying 15,153 feet above sea-level, ranks next to the Broken Hill Mine of Australia in productivity. Between 1873 and 1901 it yielded no less than 4,520 tons of silver, of an estimated value of £23,200,000. Farther south are the Portugalete mines, once very productive, and, near the Argentine frontier, those of Lipez. The silver-mines on the snow-clad slopes of Chorolque (18,452 feet), like those of Potosi, are situated to the east of the Cordilleras.

The long coastwise strip of territory on the Pacific side of South America which we call Chile is, like most of the Andean States, rich in silver. The country is for the most part, as befits a land of mountain and desert, sombre in colouring and savage in aspect. Practically all the silver-mines are to be found in the Andean region, where the great masses of brown rock show their rugged outlines sharply defined against a sky of cloudless blue.

Generally speaking, the silver-mines of Chile may be classified into four zones or districts which are distinguished from one another by the presence of various metals associated with the silver, and other variations in the ores. First there are the mines to

the north of the Huasco valley, which are richest in silver, but also contain gold and copper. Then there is the district between Huasco and Coquimbo, in which there is to be found chloride of silver and native silver. In the third place there is the part between the valleys of Coquimbo and Aconcagua, where gold-bearing lodes are most common ; and lastly there is the region south of Aconcagua, where auriferous veins are found in the granite, and mines of silver and copper are worked in the stratified rocks overlying the granites along the summits of the Andes.



Stamping Mill, Chile.

In the early days of silver-mining in Chile the ore was treated in the crudest possible fashion. Frequently the residue of the amalgamation process was kneaded up to form bricks for building purposes,

but when more scientific methods were introduced it was discovered that these bricks contained as much as 60 oz. of silver to the ton, and " houses were pulled down in all directions." *

The *tina* process of silver-ore treatment was formerly largely employed in Chile. The ore was crushed by means of a Chilian mill and was then placed in *tinas* or wooden tubs with iron bottoms. After the addition of water and a large quantity of mercury, the charge was stirred and ground by means of iron agitators. In the Francke-*tina* process the silver-bearing ore undergoes a form of roast-amalgamation. It is roasted with salt to convert the sulphides into chlorides. The pulp is then treated in *tinas* with a 10 per cent. solution of brine. The charge is stirred and heated, and mercury is added at intervals.

The mines in the northern province of Copiapo may be taken as typical of Chilian silver-mines in general. Perhaps the most important of them all is the well-known Chanaracillo Mine. The lode was discovered in 1831, and up to the year 1853 the mine had yielded no less than 2,035,424 lb. of silver. The limestone through which the vein passes is most probably of the same age as the silver-bearing limestone of Nevada. This rock is charged with silver in minute particles, the ordinary joints are charged with silver ore, and the joints near the lode with native silver. In 1856 the silver derived from each ton of ore amounted to 466 oz. Troy. The vitreous, red, and rarer ores yielded 90 to 100 oz. per ton.

Antofagasta is the port for the famous Caracoles mines, which are 10,000 feet above ordnance data. The name Caracoles, which means " snail " in Spanish, is said to be derived from the ammonites or fossil shells

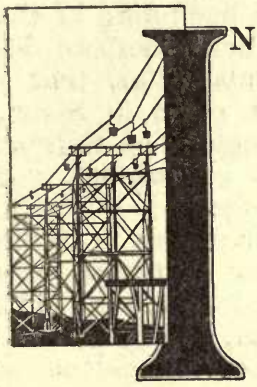
* Boyd, " Chili, 1879–1880."

which are found in the local strata. At Tocopilla the whole hillside is covered with workings which are connected by tracks, presenting a very peculiar appearance as seen from the sea. The Chilean coast for the most part consists of barren, rocky, and perpendicular cliffs of great height. Many of the mining ports are mere collections of corrugated iron shanties crowded at the base of the cliffs, and connected with the mines in the interior by light railways. Caldera and Chanaral are the chief ports for the rich mines of Copiapo. Chile is the land of contrasts in mining matters. Donkeys and mules may still be seen carrying loads of ore from some of the older mines, while others are to be found, even in the most remote districts, equipped with the most modern machinery and labour-saving devices. At Copiapo there are electric-power installations for rock-drills, pumps, and machine works. The total Chilean output of silver in 1899 was 5,772,791 oz.

We have seen then that, as was to be expected in a region where saline deposits are so common, chloride of silver is the prevailing argentiferous ore of South America. This great Andean axis of the southern half of the American Continent has been so productive, and is so rich in the ores of silver, that were it the sole silver-producing zone it would still deserve the title of Argent America. But, as we shall see, South America cannot very well retain the title of the Silver Continent, for in more modern times North America has made a bold bid for premier honours in the production of silver

CHAPTER XII

OLD WORLD SILVER-MINES



IN the meantime—while all these sensational discoveries of silver were being made in the Western Hemisphere, and mine after mine was producing wealth beyond the dreams of avarice and sending eastwards the priceless cargoes of the treasure-galleons—those argosies of the Atlantic—what of the Old World mines? While the markets of the world were flooded with Spanish-American silver, the European mines, which were productive on a much smaller scale, passed through a long period of decline and semi-neglect. Silver had become cheaper, and silver-mining in Europe was hardly remunerative. With the outbreak of the Spanish-American revolution, however, as in the case of gold, the stoppage of transatlantic supplies was the beginning of a new era of prosperity to the mines of Europe—an era which was destined to last until once again wonderfully rich finds of the white metal were reported from the New World, this time from North America.

The vicissitudes of silver-mining in Europe are exemplified most clearly perhaps in the case of Spain. Spain, as we know, is one of the oldest silver-producing countries in history. The Iberian mines were worked

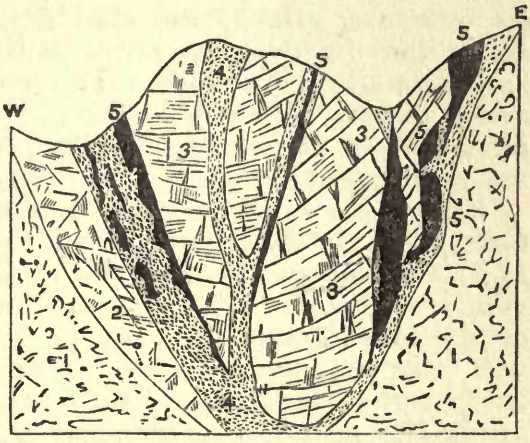
by the Carthaginians, and those of lead and silver along the southern slopes of the Sierra Nevada by the Romans. During the Moorish occupation the silver-mines flourished, but declined after their expulsion. This neglect of the mineral resources of Spain was of course directly due to the great rush to the West which followed the discovery of America and the rich finds made there of the precious metals.

For centuries there was little or no silver mined in Spain. It was not, in fact, until the beginning of the nineteenth century, after the loss of her American dominions and the close of the Peninsular War, that a revival of the mining industry took place in Spain, in common with the other mining regions of Europe. The Spanish mines were opened to all nations and much-needed new capital was introduced.

So numerous are the veins of silver ore in Spain that, after being prospected for many centuries, new lodes have been located even in modern times. The richest of them all, the Hiendelaencina, was opened up so late as 1843. A lode of silver-bearing galena or lead ore was discovered in 1839 in the neighbourhood of the ancient mines of Cartagena which yielded 1800 *arrobas*, or about 20 tons, of lead ore per day. The galena of Linares in Jaen gives about 9 oz. of silver per ton. The lead ore of the Jaroso vein of the Sierra de Almagrera, between Cartagena and Almeria, is extremely rich in silver, yielding as much as 130 to 180 oz. to the ton, while that of Hornachos produces 100 oz. to the ton. Silver-bearing copper ore is found at Ciudad Real. The total production of silver in Spain during the year 1899 was 5,448,019 oz., but in 1905 it had declined to 3,774,989 oz.

Austria-Hungary, too, has long been a great silver-producing country, the two principal mining regions being Hungary and Bohemia. Of Hungarian mines

those of Lower Hungary and the Banat are the most productive and important. The argentiferous galena veins of Schemnitz in Lower Hungary, which are seven in number, run from east to west and are from 1,000 to 2,000 feet apart. The principal lode, the Spitalberg, is known to extend a distance of 3 miles and is from 10 to 12 feet wide. At the Windshact a depth of 330 yards was reached on this lode, where bunches of silver ore were found scattered through the gangue. Another lode, the Biebergang, was worked to a depth of 1,300 feet and for a length of 3 miles. It yielded an immense quantity of silver down to the depth named, but beyond that the galena or lead-ore contained less and less silver.



CROSS SECTION, SIMON JUDAS MINE, BANAT.

The other famous mining district of Banat in south-eastern Hungary lies among the mountains that enclose the valley of the Danube at Orsova. Most of the minerals—which, besides silver, include gold, copper, zinc, lead, and iron—belong to the group of contact deposits and are richest near the surface. For the most part they have apparently been deposited as sulphides, which character they retain in depth, though near the surface they have become oxidized by the action of the elements and the atmosphere.

Silver is found near Dognacska associated with lead and copper. At the Barbara Mine the ore is sorted into three qualities, viz., oxidized lead ores, silver-bearing galena, and cupreous pyrites. In these mines the ore deposits are usually found under the hanging wall of limestone. At the old mine of Simon Judas the ore was an argentiferous copper. The ores contained 18 oz. of silver per ton, but latterly became too poor in depth to repay working.

Other notable Hungarian mines are the mine of Grossgrube in Felsobanya, and those of Nagybanya and Abrudbanya in Transylvania. The Grossgrube vein is said to be, in structure, almost the counterpart of the great Comstock Lode in Nevada. This mine was very productive in olden times, although worked by imperfect processes. The former presence of rich ore bodies near the surface may be inferred from the shape and character of the old Roman workings near the outcrops. Extensive "chimneys" of silver ore have been entirely removed by the Roman miners.

In the sixteenth century the Austrian production of silver was about 800,000 oz., or twice the German and half the total European yield. The output diminished in the following century, to be again increased. In modern times, owing to the adoption of new and improved methods of ore treatment, the yield has increased until in the year 1905 it reached a total of 1,800,000 oz. Silver is mined at Pribram and Joachimsthal in Bohemia. The latter is a very ancient mine, and is now over 2,000 feet deep. The mines on the Bohemian side of the Erzgebirge are very similar to those on the Saxon side, the central boss or ridge of the mountains consisting of granite, which is succeeded on both slopes by gneiss and slaty rocks.

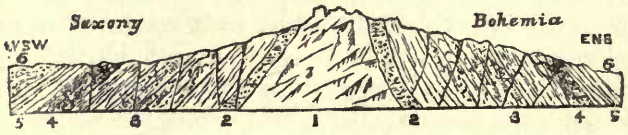
The beginnings of mining on the Saxon side of the Erzgebirge date back to the twelfth century. About

the year 1170 a Bohemian labourer, travelling through the forest which then covered the site of the present town of Freiberg, sat down to rest by the wayside. He saw a stone lying at his feet which resembled others he had seen in the Hartz. He broke off part of it, carried it with him, and, as soon as he could, had it tested. It proved to be galena or lead ore, rich in silver. Some time afterwards he returned with several comrades, and searched for the lode from which he supposed the stone to have been derived. These early prospectors were successful in their quest. Several years later there was a revolt among the Hartz miners. The Duke of Brunswick had insulted the wife of one of the officers of the mines. The miners thereupon left the district, and following the lead of one of the discoverers of the Freiberg lode, established themselves in a village close by, which they called Christiansdorf. This village afterwards grew into the town of Freiberg. Fresh veins were located, and the mines grew in number and developed in productivity. The town became prosperous and rich. Its fortunes suffered an eclipse during the Thirty Years War, but again it prospered and became famous for the school of mines of which Werner was a distinguished professor. Even to-day, although some of the mines are exhausted and others are worked at great depths, Freiberg is the chief mining centre of Europe. It is the classic ground of German metalliferous mining.

The Freiberg district is famous too as the scene of the labours of Georg Agricola or Bauer (1490–1555), the German scholar and scientist known as the " father of mineralogy." After finishing his studies in the " new learning " and visiting Italy, he settled down as a practising physician at Joachimsthal, partly " to fill in the gaps of healing," and partly to test what had been written about minerals by a careful examina-

tion of the ores and the methods of ore treatment. The result of his investigations, the volume *Bermannus, sive de re Metallica Dialogus*, the first attempt to systematize on scientific lines the knowledge gained by practical work, was published in 1528. Two years later Prince Maurice of Saxony appointed Agricola his historiographer, and the scientist removed to Chemnitz. After writing several other books on geology and mineralogy, Agricola's most famous work, *De re Metallica*, was published in 1556. It was the first complete and exhaustive treatise on mining and metallurgy, and long remained a standard work.

Turning to the practical mining aspects of the district, we find that the strata on the Saxon slopes



SECTION ACROSS ERZGEBIRGE.

of the Erzgebirge, near Freiberg, are traversed by no fewer than nine hundred distinct lodes, which are usually classified into four groups, each having more or less affinity with the others. The first group is generally called the precious quartz group, and includes about 150 veins varying from six inches to a foot in width. The quartz is often intermingled with fragments of the adjoining rocks, and is sprinkled with pyrites. The metalliferous minerals are found in cavities in the veins, and irregularly distributed throughout the quartz. The silver ores obtained include silver glance and antimonial mineral. These lodes attain their maximum development and productivity near Braunsdorf.

The second group consists of brown spar veins,

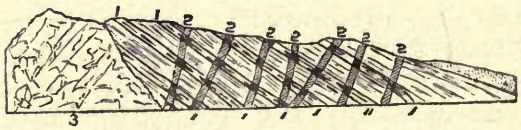
and is known as the precious lead group. It numbers about 340 lodes, which contain quartz as well as brown spar, and lead ore rich in silver, blende, and iron pyrites. These minerals are often beautifully arranged in layers. In the cavities are found silver ore and lumps of native silver, some of which have weighed as much as a hundredweight. The third or barytic lead group comprises some 130 veins, which are strongest and contain most silver ores north of Freiberg. Finally, the fourth, also called the pyritic lead group, lie east of Freiberg. The veins number close on 300, but they are only from 2 to 3 inches in width. The ores include galena, blende, mispickel, and the usual silver ores. The average proportion of silver in this region is about 49 oz. to the ton. The lodes become copper-bearing at the Jungehoheberk and Morgenstern mines.

Of the methods of silver-ore treatment in use at European mines, one of the best known was the Freiberg or barrel process. The ores, after being roasted with salt, were placed, along with an admixture of mercury, iron, and water, in barrels, which were made to rotate so that the ingredients were thoroughly mixed. The solution and precipitation were continuous, and the separated silver united with the mercury to form a semi-fluid amalgam. The process was, however, on account of the absence of external heat, and the great care necessary in manipulation, found to be too slow and cumbrous for modern requirements, and was abandoned about the year 1856. But, both before and since, the Germans in the Erzgebirge district have, with characteristic thoroughness, almost invariably led the way in scientific mining methods. The total yield of silver in the Freiberg mining district from 1524 to 1850 is estimated to have been 5,613,228 lb. Troy.

Next to the Erzgebirge the most important silver-mining region in Germany is the Hartz. At Andreas-

berg the chief silver and lead mines are the Samson and Neufang, opened up in 1520, and now about 3,000 feet deep. The principal mines at Clausthal are the Dorothea and the Carolina. The former, between 1700 and 1807, produced silver to the amount of 553,200 lb. It is now, however, practically exhausted, and the Carolina has become the more productive mine of the two. The total silver production of the German mines in 1905 weighed 12,535,238 oz.

The most celebrated silver-mine in Europe is undoubtedly that of Kongsberg in southern Norway. Lying in the shadow of the Jonksnut Mountain and near the falls of the River Laagen (Labrofos), some sixty miles W.S.W. of Christiania, the first discovery of silver was made by a peasant in 1623. Mines were opened up at once, and the wooden mining town of Kongsberg grew up rapidly round the workings. Kongsberg during the eighteenth century was more important than it is now, and contained double the present population of about 5,500. With the exception of short intervals the mines have been worked with varying success until the present day. The ore occurs at the Kongsberg Mine, not in true lodes or veins, but in a succession of layers, of partly decomposed rock known as *fahlbands* or "rotten belts." There are



SILVER FAHLBANDS AT KONGSBERG.

seven of these layers, interstratified with slaty rocks with the structure of which they have much in common, They have been found to be productive of silver over a length of several miles and a breadth of about 1,000

feet. The ore is scattered throughout the layers, but not in sufficient quantities to pay for mining in the solid rock. These rotten belts are, however, traversed by true veins, also containing silver ores, and the profitable deposits of ore lie at the junction of the veins with the *fahlbands*. The veins, like the bands, are too poor to work alone at any distance from the point of intersection. Bonanzas have been located down to a depth of 1,800 feet.

The best specimens of crystallized silver have been obtained from Kongsberg. Large masses of native silver have, too, been found in the Norwegian mine; one brought up in 1666, weighing 560 lb., is still preserved in Copenhagen museum, and another, of 750 lb. weight, was disinterred in 1834. The Government smelting works and mint are situated in the town of Kongsberg. The yield of the Government silver-mines in 1899 amounted to 172,515 oz. troy.

The Siberian silver-mines are the most important in the Russian Empire, but, compared with those of the great silver-producing countries of the world, they pale into comparative insignificance. The best known are the mines of Nerchinsk, which lie to the east of Lake Baikal. The lead ore is rich in silver, and the deposits, like those of most of the Siberian mines, are worked by convict labour. Further westward, and in about the same latitude, are the Kolivan mines in the Altai Mountains, where the silver ores are associated with those of copper, gold, and lead. Here the silver-bearing ore was formerly quarried in open workings as well as in underground galleries, and after the ore was sorted the silver was obtained by smelting.

A considerable proportion of the world's silver is obtained from lead-mines where the former metal is present in comparatively small quantities. Lead is, of course, widely distributed in nature, and a small

percentage of silver is almost invariably present. In the United Kingdom, for example, although there is not a single silver-mine proper, the production of this metal amounted in 1876 to 483,422 oz. Of individual mines the Great Laxey Mine in the Isle of Man gave the highest yield of silver, 2,500 tons of ore producing 103,332 oz. of the white metal, or over 40 oz. to the ton. On the whole, the amount of silver obtainable from the lead ores of British mines appears to be declining, as in 1899 it was only 191,927 oz., of an estimated value of £21,942.

But in countries where the production of silver is small and is obtained mostly from lead, a point is reached when it is no longer profitable to work the mine, or to treat the ore for silver. During the last generation many Old World mines have found it impracticable and unremunerative to continue to treat the ores for silver, on account of the fall in price due to the immense supplies from the Silver States of North America placed on the market.

CHAPTER XIII

THE SILVER STATES

JUST as, on the western slopes of the Sierra Nevada and the Rocky Mountains of North America, stretching right away to far Alaska, gold-bearing quartz veins and placers are to be found, so along the eastern foot-hills of the Sierra and the Rockies, and extending southwards to Mexico, is a chain of silver-mines that for purity and plenitude of output have seldom been surpassed. Through central Mexico, Arizona, central Nevada and mid-Idaho runs another series of silver-mines, the ores of which are mineralized with a complex association of the baser metals. To the east again, in New Mexico, Utah, and Western Montana, lies yet another zone, this time of silver-bearing lead ores.

The phenomenal productivity of the Californian gold-fields had attracted, as we know, a miscellaneous floating population to the Pacific slope. With the exhaustion of the placers the hardier and more intrepid spirits ventured into the unexplored mountain fastnesses of the hinterland in search of the precious metals. To these adventurous pioneers, the advance guard of

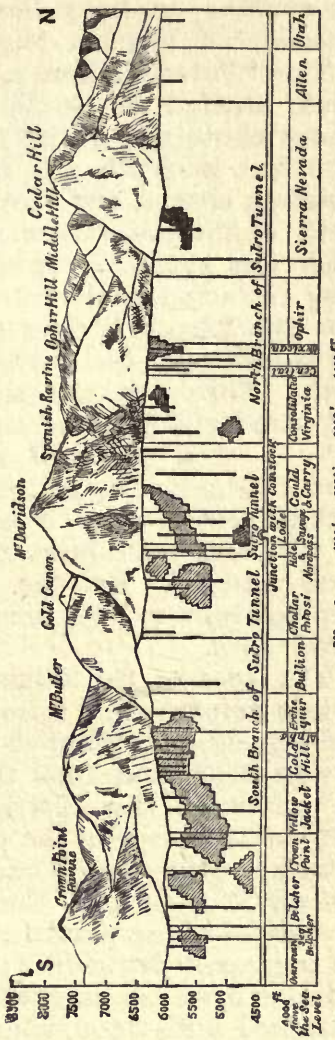
an ever-changing Western mining population, we are indebted for numerous important discoveries which have added very materially to the world's stock of silver as well as of gold.

In the year 1859 Peter O'Reiley and Patrick McLaughlin, two of these pioneers, were prospecting at the head of Gold Cañon, near the present site of Gold Hill, in the mountain ranges east of the Sierra Nevada. They were working what they supposed to be a gold-placer, and while washing the "pay-dirt" they found, intermingled with the scales of gold, a heavy, black, earthy substance which seriously interfered with their method of gold extraction. Comstock, a member of another party, laid claim to their holding. It was decided to send one of the party to Sacramento to ascertain what the "black stuff" was. The mineral was examined and tested, and turned out to be sulphide of silver. The prospecting party had been working on the decomposed outcrop of the famous ore deposit which was afterwards called after Comstock, who soon became the leading owner. Such was the first discovery of silver in the United States, and it is hardly necessary to say it created great excitement among the miners of Western America.

The great Comstock Lode runs north and south along the eastern slope of a range of hills lying about fifteen miles eastward of the Sierra Nevada. The mining camp that sprang up round the original workings has now blossomed out into the prosperous mining community of Virginia City, which may be found on the map to the south of the Central Pacific Railway and between Lakes Bigler and Carson. The lode occurs at the junction of two dissimilar formations. It has been traced for a distance of over four miles, and upwards of 35 mines have been opened up along its course, the richest and most productive being known as the

great bonanza mines. The width of the lode varies from 100 to 200 feet, and it dips eastward. Gold and silver are disseminated throughout the quartz fluorspar in the proportion of about one-fourth to one-third gold and the remainder silver. The lode is not, of course, uniformly productive, there being several large bodies of ore separated by barren rock.

Beginning at the north of the reef, four large ore bodies have been located and worked between the Utah and the Chollar Potosi mines, a distance of about two and a quarter miles. The first of these was in the Sierra Nevada property, and contained gold and silver ores of from £1 to £2 per ton in value. Between this and the next ore body is a stretch of about 1,600 feet of barren ground. This second ore body in the Ophir and Mexican claims is practically denuded of its rich ores, of which it has yielded immense quantities. At a depth of about 700 feet the lode was "pinched" out, the quartz disappearing;

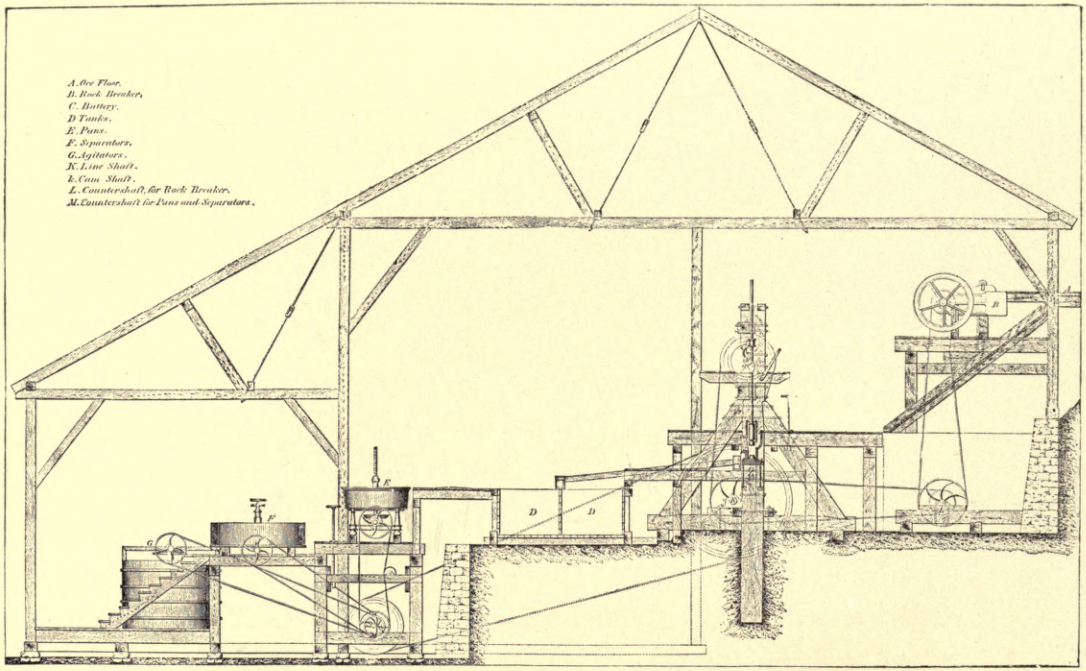


LONGITUDINAL SECTION ACROSS COMSTOCK LODE.

but another ore-body lies at a greater depth in the Consolidated Virginia Mine not far away.

The " Potosi Chimney," as the next ore-deposit was called, started in Gould and Curry's ground. This famous chute was over 2,000 feet in length and about 1,000 feet in depth. It was one of the richest of the Comstock chutes, and yielded something like £3,000,000 worth of the precious metals. At one time the ore, which was valued at from £17 to £25 per ton, was being extracted at the rate of 650 tons per day. Those were the " boom " days of the great bonanza mines. The workings of the Savage Mine have reached a great depth. This was the shaft which was pierced by that wonderful piece of engineering, the Sutro Tunnel, at a depth of 2,200 feet. The last of the great ore-bodies extended from the Exchequer Mine to the Crown Point. From this deposit also most of the rich ores have been extracted, leaving only lower-grade mineral. On the whole the deeper deposits have not been so rich nor so largely productive as the higher ones.

The ores of the Comstock Lode consist chiefly of various sulphuretted forms of silver, native silver, and gold—finely disseminated in the quartz. In the period between 1862 and 1868 the average annual output of the mines in this district was $11,000,000. From 1873 to 1878, when the great bonanza mines were in operation, the yield had increased to $26,000,000 annually. After 1877 the production began to decline, on account of the partial exhaustion of the ore supplies, the increased expenditure in mining at great depths, and the decrease in the price of silver. This decline continued until 1899, when, owing to the adoption of improved methods and machinery, the output once more began to increase. So remarkable have been the advances in mining methods on the Comstock Lode



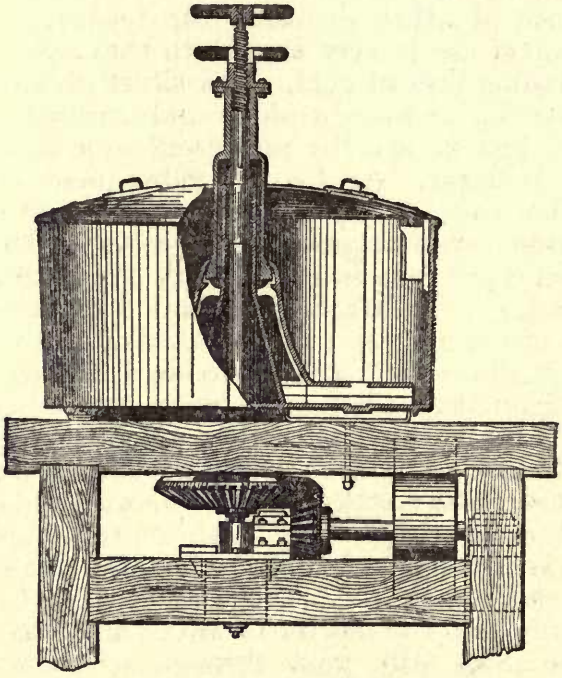
SECTION OF SILVER MILL.

that it has been called the mining school of the world. It has been found practicable, too, to treat the old tailings by the cyanide process with profitable results. Altogether it is estimated that the Comstock mines, up to the end of the year 1902, produced silver to the value of $204,653,040.

In dealing with the ores of the Comstock Lode, as with those of other deposits, the treatment of free-milling silver ore is very similar to that applied to the corresponding ores of gold. The silver ores of Nevada are broken up in rock-breakers and crushed in stamp-batteries, just as are the auriferous ores of Johannesburg or Ballarat. As for the subsequent treatment, the Washoe process of pan-amalgamation has long been the leading raw-amalgamation process of the United States, where it was introduced by Mr. A. B. Paul in 1861. Briefly, the Washoe method comprises the wet crushing of the ore, the settling in tanks of the resultant sands and slimes, and the subsequent further grinding and amalgamating of these pulps in steam-heated iron pans, with or without the addition of chemicals.

The Washoe process, though not dissimilar in principle to the *Patio* method, is much more rapid in action, and will deal satisfactorily with more complex ores. The ore is usually broken in pieces the size of an egg in the rock-breaker, and is then pounded in a Californian stamp mill, into the mortar of which water is admitted until the pulp will pass through a 40-mesh sieve. The pulpy liquid is discharged into wooden settling tanks. The settled contents of these are shovelled into the amalgamation pans, each of which holds about two tons of pulp. The vessel in general use is a combination pan which has a flat cast-iron bottom 5 feet in diameter, and wooden sides 30 inches high. In the centre is a hollow cone, through which passes the driving shaft, geared from below. This turns the grind-

ing apparatus—a driver with a "muller" which can be raised or lowered. Grinding plates, which can be replaced when worn, are attached to the bottom and sides. Under the bottom of the pan is a steam-chest by means of which the pan and its contents are maintained at a regular heat. In working, the muller



COMBINATION PAN.

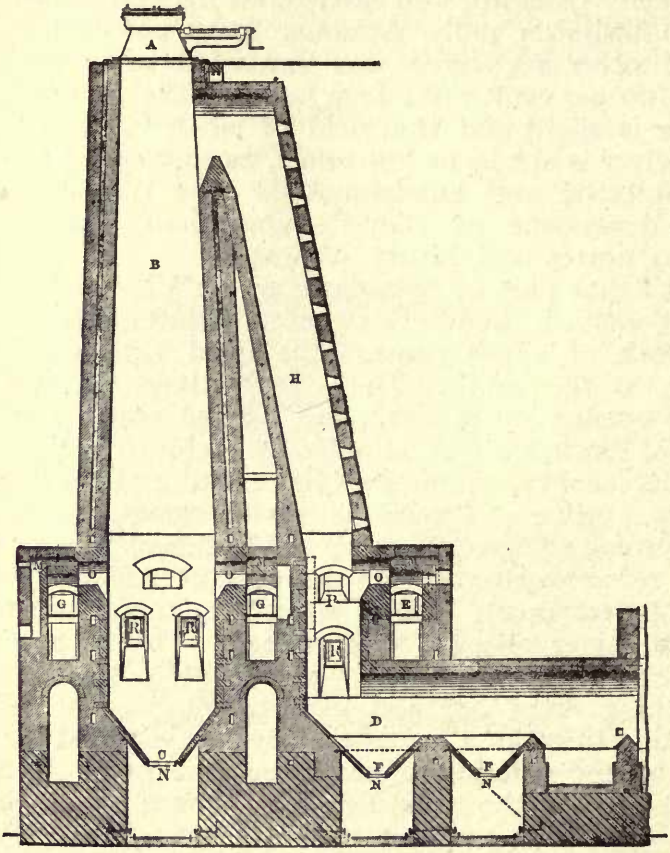
is slightly raised, water is introduced, the pan is charged with the crushed ore, and the charge is ground for three or four hours. Salt and blue-vitriol are very often added, either previous to or simultaneously with the insertion of the quicksilver, when further grinding and mixing follows. The object is, of course, to grind the

ore into as fine a pulp as possible in order to facilitate the amalgamation of the silver with the mercury. The process goes on very rapidly. According to one authority (Austin), who carried out his investigations at the Charleston mills, Arizona, 92·13 per cent. of the total silver recovered was extracted after one hour and 100 per cent. after four hours. The loss in quicksilver is slight and the yield of silver fairly high, but the silver is apt to be low-grade, as copper is frequently precipitated and amalgamated. The Washoe process is independent of climatic conditions, but requires cheap power and plenty of water.

All that part of Nevada in which Virginia City and the Comstock Lode are situated is intersected with a network of silver veins. The Gold Hill lodes lie a little to the south. The Reese River mines, which were opened up in 1862, are located about 100 miles east of Virginia City. Hundreds of veins were discovered in this locality, running mostly north and south. The faults, owing to volcanic disturbances, were very numerous, and caused considerable difficulty in working. The refractory nature of the ores necessitated exceptional treatment, and a special method, called the Reese River process, was devised. This is a variant on the pan-amalgamation process, and consists in dry-stamping dried ore and salt, together or separately, roasting them in a reverberatory furnace, and amalgamating the chloridized ore in an iron pan. With the exception of the roasting, the general arrangements and apparatus are not unlike those of the Washoe process. The amalgamation of roasted ore is, however, much more rapid and effective than that of unroasted. The chief drawbacks are the extra expense of roasting, the difficulty of dry as compared with wet crushing, and the greater impurity of the amalgam.

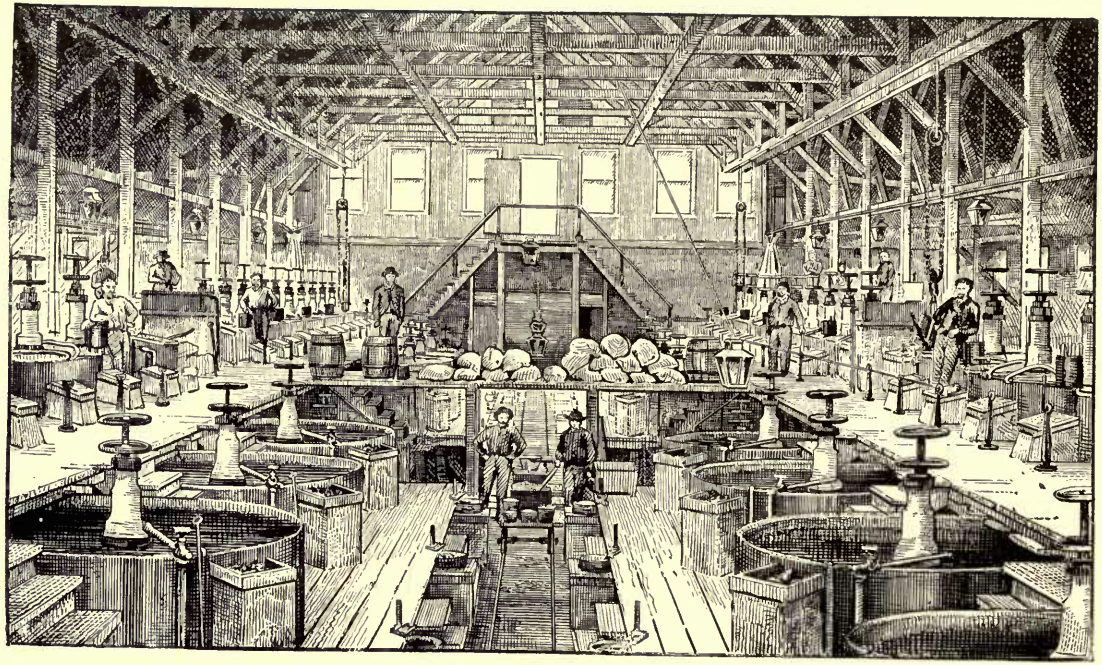
With ores that contain sulphur the Stetefeldt furnace

and other mechanical roasters are found to give excellent results. The essential principle of the Stetefeldt process consists in the passing of the ore through



STETEFELDT ROASTING FURNACE.

an ascending flame, whereby the ore is not only oxidized, but, when mixed with salt, is also chloridized. To Mr. Stetefeldt the inventor was due the discovery that a complete chloridizing roasting of silver ores



PAN ROOM, CONSOLIDATED VIRGINIA MINE.

CU-UMC

can be effected in the short time it takes for a shower of mixed ore and salt to fall through an ascending sheet of flame. This roasting furnace is admittedly one of the most important inventions connected with the metallurgy of silver, as without it it is doubtful whether ore from many of the mines in the Western States could have been successfully treated.

The White Pine region, near the Utah border of Nevada, was formerly a silver-mining district of some importance. A number of miners were on their way to White Pine in the year 1864, when some of the laggards of the party, in seeking an easier path, saw some rich mineral "float" in what is now known as New York Cañon. They quickly staked out claims, but as shaft-sinking and ore-treatment required capital, little progress was made until 1869, when a small furnace was set up. Later the Eureka Consolidated Mining Company was floated and bought up numerous claims.

Soon other rich lodes were discovered, notably those at Silver Hill, Prospect Mountain, and Ruby Hill. Over sixty mines were opened up from time to time in the district, and in the midst of them sprang up the town of Eureka. This busy mining town in eastern Nevada lies some ninety miles south of the Central Pacific Railway. The range of hills to the west of Eureka lies between the Washoe ridge, containing the Comstock Lode, and the Wahsatch Mountains, and is heavily mineralized.

Ruby Hill, on which the principal mines are located, consists of granite and limestone. In the midst of the limestone beds, which have been greatly crushed and shattered, are huge caverns or ore chambers, the sides and roofs of which are lined with stalactite, while the floors are covered with a layer of metallic ores of varying thickness. The first of these caverns, the formation

of which is due partly to chemical and partly to mechanical action, was found on the site of the Champion Mine, below a surface deposit of ore. The ores consist chiefly of carbonate of lead, the richest being known among the miners as "black carbonate." In the "K.K." mine a huge mass of mineralized quartz was found in one of these ore chambers, which measured 90 feet long, 45 feet wide, and 25 feet thick. It was of a sugary texture, and, like most of the Ruby Hill deposits, was probably formed by the filtration of water charged with minerals. This huge block was

STRUCTURE OF RUBY HILL.

rich in gold and silver, and was valued at from £5 to £35 per ton.

In the year 1869 a party of prospectors started from Reese River and, travelling north-west, reached the Burnt Wagon district, which took its name from the charred remains of the burnt wagons of a party of emigrants attacked and killed by Indians. Close by was a spring, where the prospectors camped. Their search for minerals was rewarded by a splendid find of bold and rich outcroppings, which were located on what the finders called "Mineral Hill." This lucky band of pioneers sold their rights to a Californian

syndicate for £100,000. Another instance of the accidental nature of these finds of the precious metals was the discovery, by some soldiers in pursuit of Indians, of the deposits which were afterwards opened up as the famous Pioche mines in the south-eastern corner of Nevada.

Another important discovery of silver was that of the deposit on War Eagle Mountain in Idaho. Notwithstanding its distance from civilization, located as it was in an inhospitable region then frequented by roving bands of Indians, a prosperous mining community soon sprang up. Two of the most notable mines of the district closely adjoined one another—the Golden Chariot and the Ida Elmore—and this propinquity was the root-cause of one of the most sanguinary episodes in the history of mining. The shafts of the Golden Chariot and the Ida Elmore mines were only 100 feet apart, but as the workings descended, the intervening rock contained such rich ore that the owners of both mines coveted its possession and came into frequent collision as to the exact boundary line. At last, as the miners broke into the adjoining workings, these disputes culminated in physical conflict deep underground. Men armed with repeating rifles were sent down the shafts to protect the miners from behind breastworks erected in the tunnels or drifts, while the diggers were blasting the ores from the disputed bonanza. There was more than one murderous affray, and many men were killed and wounded, before this unsatisfactory state of affairs was brought to an end. Matters reached a climax in the killing of Mr. Marion Moore, the principal shareholder in the Ida Elmore Mine. Lawlessness was rampant when at last, in March 1868, the governor of the State arrived with a battalion of soldiers, and taking possession of the mines, proclaimed martial

law and succeeded in restoring order. It had been a terrible affair, costly in blood and treasure, as the companies had to pay their fighters exorbitant wages for doing patrol duty in the mines. Certainly this was one of the most remarkable instances on record of a bloody conflict for the possession of a rich deposit of the precious metals.

Not very long after the opening up of the Comstock Lode the western escarpments of the Wahsatch Range, in Utah, were beginning to be searched for the precious metals. Systematic prospecting began in 1862, when Colonel Patrick E. Connor, of the Third California Infantry, established Fort Douglas, near Salt Lake City. He allowed many members of his regiment who had been to the Californian diggings to prospect the district, with the result that mines were located at Stockton, Bingham Cañon, Little Cottonwood, and elsewhere. Attempts to smelt the lead-silver ore near Stockton about 1866 were unsuccessful, and silver-mining did not become an established industry in the State until about 1870. In addition to this the development was slow because of the inadequate transportation facilities and the inaccessibility of some of the deposits.

The principal silver-mines of Utah are situated in the Wahsatch Mountains, which run north and south at a distance of about 20 miles east of Great Salt Lake. The higher peaks of the range reach an altitude of 12,000 feet. Numerous streams come leaping and tumbling down the deep cañons that furrow the side of the range. It is up the most southerly of these, the Little Cottonwood Creek, that the Emma and several other mines are situated. Ascending from Salt Lake City up this creek to the higher part of the range, a natural section of the geological structure of the mountains is afforded on a grand scale. Great granite peaks covered with snow rise on either side. This grey

granite continues for 5 or 6 miles, when after passing a series of strata, the carboniferous limestone is reached. It is there that the ore deposits are located, and the Emma and its associated mines are worked. The Emma is famous for the immense size of the great ore chamber which formed the major part of its deposit. The ores varied in value from 25 to 156 oz. of silver per ton. The absence of lime in the ore in the midst of limestone is remarkable. Other notable silver-mines in Utah are the Flagstaff, the Silver Star, and the Exchequer, but the principal silver-producing districts to-day are the Tintic (argentiferous copper) in Juab and Utah counties, and the Park City (lead and zinc ores) in Summit and Wahsatch counties. The total production of the state in 1908 weighed 8,451,338 oz., and was valued at $4,479,209.

Generally speaking, silver occurring in or near the older rocks, as in the Comstock Lode and in the quartz portions of the Ruby Hill deposits, is found in ores which may be separated by mechanical means and amalgamation, and are known as free-milling ores. As found in the limestones of Ruby Hill and the Wahsatch mountains, however, the silver is chemically blended with lead and other metals, and requires to be smelted before it can be separated.

Turning to Colorado, we find that, although some of the earlier discoveries of gold were made within its borders, the fact that rich deposits of silver were also present was not realised until a much later date. The mineral deposits round Leadville, the most important and characteristic mining town in Colorado, share with the Comstock Lode the distinction of being enormously productive in both gold and silver. Leadville is one of the most celebrated mining camps in the world, and one of the highest, lying as it does about 10,150 feet above sea-level. It is situated on the western slope of

the Mosquito Mountains, just where the Arkansas River carves its way between the Mosquito and Sawatch ranges. We know that placer gold was located in California Gulch in the spring of 1860, and that by July the mushroom "Oro City" had 10,000 inhabitants. But the boom only lasted five years, and as the gold supply dwindled the population followed suit. For many years the "heavy sands" and great boulders which interfered with the working of the gold-placers had been carelessly removed. At last, in 1877, it was found that these boulders were fragments of enormous deposits of lead carbonate, rich in silver, which were located by a man named Stephens on the adjacent hillsides. In December of the same year several hundred miners had reached the spot, and by January 1878 Leadville had sprung into being. In these early years it was one of the most turbulent and picturesque of all the mining camps of the West. The population increased very rapidly, and at the end of 1879, it is said, reached a total of 35,000.

The ores in the Leadville district occur in a blue limestone overlaid by porphyry, and the best grades contain not only gold and silver, but also copper, lead, and zinc. Mining methods were at first extremely primitive, but remarkable advances have been made in the capacity and character of the winding, pumping, and smelting apparatus. The cheapening of the cost of coal, explosives, and other supplies, and also of transport, has, too, made it possible to apply economic and scientific processes to the treatment of low-grade ores hitherto deemed unprofitable in working. The value of the Leadville output during the years 1879–1889 was $147,834,186. The decline in the price of silver about the year 1893 threatened the future of Leadville, but fortunately the source of the gold-placers had been discovered, and there began a new era

of prosperity. There was a disastrous strike among the miners, which began in June 1896. Rioting broke out in September, and militia guarded the mines for months. In January 1897 the mines on Carbonate Hill were flooded after the removal of the pumps, and some of them were not reopened for years. The strikers returned to work in the following March.

The increase of output more than doubled between 1890 and 1900. From 1879 to 1900 the total output of precious metals from the Leadville mines is estimated to have reached the immense value of $250,000,000.

The silver deposits in the Red Mountain district of Colorado began, in the year 1881, to attract considerable attention owing to the phenomenal productivity of several mines in that region. The chief of these were the Guston and the Yankee Girl mines. The ore deposits in this part of the Rocky Mountains are situated in a great fissure filled with porphyry carrying the ore in large chutes or chimneys. The course of the dyke is clearly marked upon the surface by what the miners call "quartz blow-outs." These are harder portions of the dyke, which have resisted the action of the elements better than the surrounding rock, and so stand out above the surface as landmarks. The miners have a rough-and-ready rule that wherever these "blow-outs" are found and are even slightly mineralized, there are rich bodies of ore in depth. Usually this appears to hold good, for many such ore-bodies have been found at a depth of 200 feet, although there was no rich ore near the surface. A sample of ore taken in the Guston Mine some years ago, at a depth of 300 feet, assayed 17,050 oz. of silver to the ton of 2000 lb. This was, however, taken from an exceptionally rich pocket of mineral. The ore at the outcrops on the surface is a sulphide of copper, lead, and iron, but the percentage of lead and

iron decreases in depth and the ore becomes almost pure stromeyerite or sulphide of copper and silver.

Operations were begun at the Yankee Girl Mine in 1882, and the first 50 feet of sinking yielded 2,000 tons of ore, which was sent to St. Louis, and after paying all expenses of mining, treatment, and transport, gave a profit of £12 per ton. It was in this mine that the wonderfully rich pockets of stromeyerite were first encountered. Enormous quantities of ore were taken from it, which, it is said, realized from $20,000 to $30,000 per truck-load of 10 tons.

Many of the silver-mines of Colorado are situated at an altitude of 11,000 feet above the sea. At that elevation the air is greatly rarefied and has a marked effect on the respiration of the miners, and more particularly on the new-comers. The air-compressors used in connection with the rock-drills are also said to lose efficiency from the same cause.

About the year 1894, owing to the heavy fall in the price of silver, many of the mines in this district had to close down, and some of the mining camps were abandoned.

The territory which we now call Arizona has long been known to be rich in minerals, and traces of crude prehistoric mining have been frequently found. Between 1610 and 1660 the Spaniards sent several expeditions northwards from Mexico into California, Arizona, and New Mexico in search of gold and silver. The deposits located in the mountains of New Mexico were worked by the Indians, who under the Spanish *martio* law were little more than slaves. They revolted in 1680, and the mines were abandoned for nearly a century. In 1738 a remarkable deposit of silver nuggets was found at Arizonac, but it was exhausted in the brief period of three years.

In an old Spanish work entitled "Apostolic Labours

of the Society of Jesus," an account is given of the discovery of silver in the Santa Rita Mountains:

"In the year 1769 a region of virgin silver was discovered on the frontier of the Apaches, a tribe exceedingly warlike and brave, at the place called Arizona, on a mountain ridge, which hath been named by its discoverers Santa Rita. The discovery was made known by a Yaqui Indian, who revealed it to a trader of Durango, and the latter made it public. News of such surprising wealth attracted a vast multitude to the spot. At a depth of a few *varas* masses of fine silver were found, of a globular form, and 1 or 2 *arrobas* in weight (an *arroba* is 25 lb.). Several pieces were taken out weighing upwards of 20 *arrobas*; one found by an inferior official attached to the Government at Guadalajara weighed 140 *arrobas*. Many persons amassed large sums; whilst others, though diligent and persevering, found little or nothing. For the security of this mass of treasure the captain of the Presidio of Altar sent troops, who escorted the greater bulk of this silver to headquarters, whereupon the officer seized the property as being the property of the Crown. In vain the finders protested against this treatment, and appealed to the audience chamber at Guadalajara, but for answer the authorities referred the matter to the court at Madrid. At the end of seven years the King made the decision, which was that the silver pertained to his royal treasury, and ordered that henceforth the mines should be worked for his benefit. This decree," concludes the chronicler, "together with the incessant attacks of the hostile Indians, so discouraged the treasure-hunters, that the mines were abandoned."

Then there is a hiatus in the history of mining in Arizona. Not until the second half of the nineteenth century were any further finds made. Of these, as far

as silver is concerned, the deposit which bears the significant cognomen of Tombstone was the most important. The mines were opened up and flourished from 1879 to 1886. Then followed a period of depression and declining productivity, but about 1905 Tombstone once again became the centre of important mining interests. Broadly speaking, the silver lodes of Arizona follow the general stratification, and many of them extend for miles. Those of the Globe district correspond to the class to which the Comstock Lode also belongs. The total silver yield of the mines of Arizona in 1905 was $1,573,850.

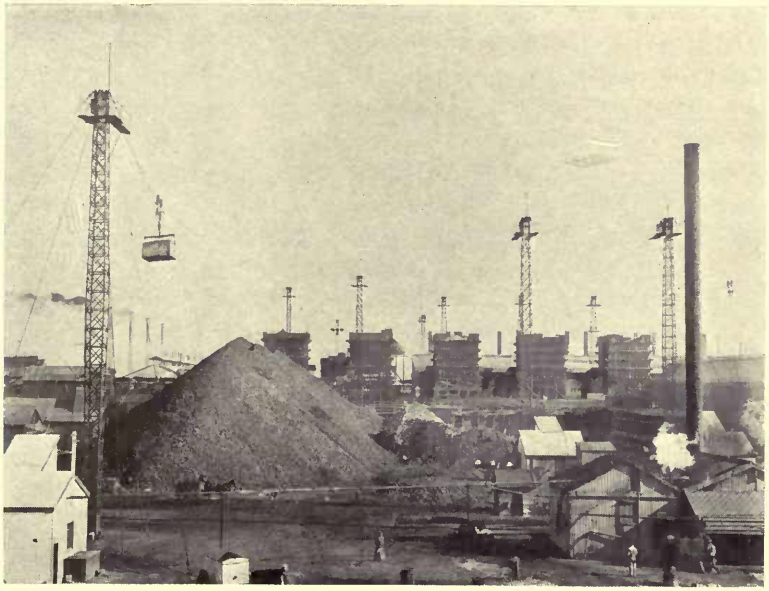
In addition to the amalgamation treatment of silver ore, there is another which is very largely used, not only in Arizona, but in other parts of America, and also in Europe. I refer to the lixiviation, leaching, or liquid solution process of which the cyanide treatment is but a single phase.

Free-milling ores, or those suitable for amalgamation, can also, as a rule, be successfully leached. In leaching or lixiviation, the silver ore is subjected to the action of solvents which dissolve the silver, the metal being afterwards recovered by precipitation. One of the earliest methods of extracting silver from its ore by means of solutions was the Augustin process, introduced in the United States by a German named Augustin in 1849. The ore was roasted with salt, and the resultant chlorides were treated with a saturated solution which precipitated the silver. Both the Augustin method and the Ziervogel process, which was introduced at Hettstadt about the same time, and which is based upon the decomposing of all sulphates except that of silver, and the leaching out of the silver sulphate with hot water, are nowadays considered practically obsolete and are seldom or never employed.

The Patera process, which was devised about the

Broken Hill Co.

GENERAL VIEW, SMELTING WORKS AND REFINERY, BROKEN HILL MINE.



Broken Hill Co.

MECHANICAL FEED OF ORE TO BLAST-FURNACES.

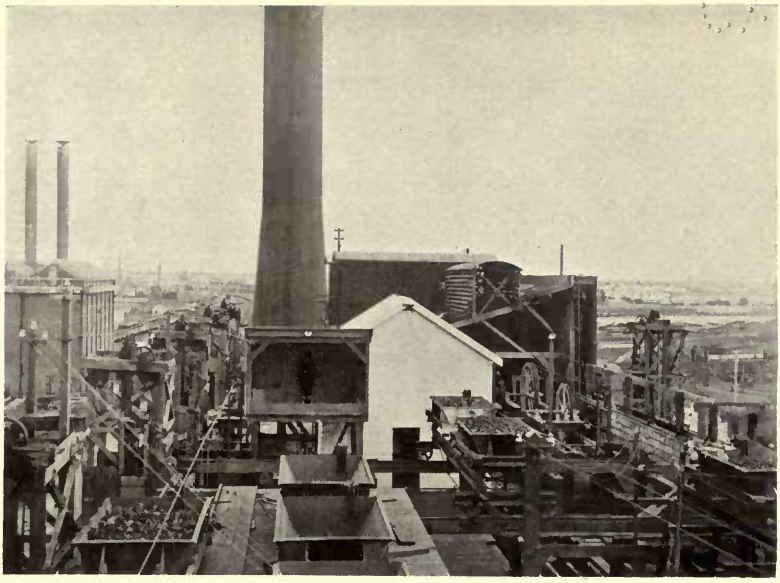
year 1853, has since been improved by Mr. E. H. Russell. Briefly the method is to take the ore, after it has been roasted with salt, and place it loosely in the leaching-vats—generally circular wooden tanks measuring from 16 to 20 feet in diameter and fitted with false bottoms and cloth or gravel filters. A washing solution is passed through, and this is succeeded by the silver solvent —a complex chemical solution. The silver solution is collected in a circular precipitating vat and again treated, when a black, muddy deposit is precipitated, containing about 50 per cent. of silver. This precipitate is filtered, dried, and finally smelted.

Lixiviation, generally speaking, has many advantages over amalgamation. The ore, in the first place, need not be so finely crushed. The first cost of the lixiviation plant is much lower, and less power and water are required. In large amalgamation plants the quantity of quicksilver in use represents a capital of from £6,000 to £8,000, while the stock of chemicals required for lixiviation does not, as a rule, cost more than one-tenth of this sum. By Russell's process the percentage extracted by lixiviation is much higher than by amalgamation. In addition to all this, the use of chemical solutions is less inimical to health than the use of mercury, which is notably injurious to the health of the workers.

Electricity has also been introduced in the metallurgy of silver. Crude silver usually contains small amounts of copper, gold, bismuth, or lead. Electrolytic methods have been devised to eliminate these impurities. The process invented by Moebius in 1884, and improved in 1895, is the best known and most important, the silver deposited by this method frequently assaying 99·9 per cent. pure. A later modification devised by Dietzel in 1899 is in use at Pforzheim and other places.

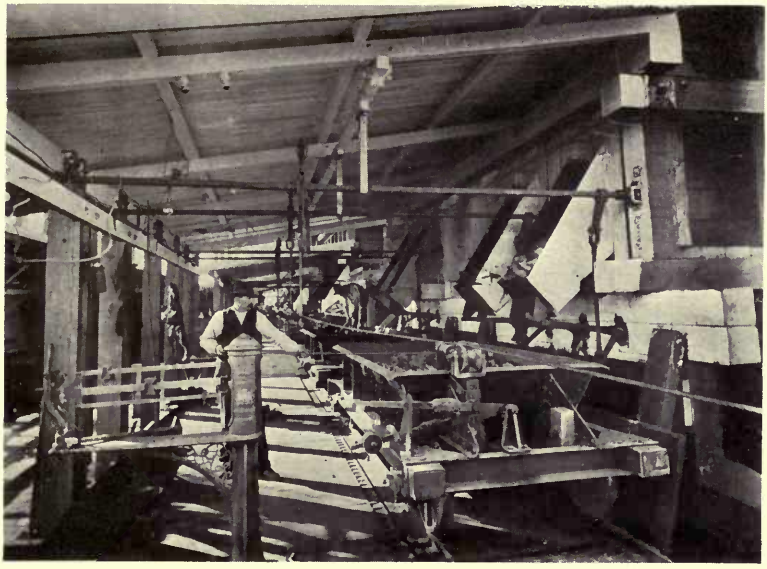
Undoubtedly the richest silver-fields of modern times are the Australian deposits of the Barrier Range at Broken Hill in New South Wales. Broken Hill lies at the southern extremity of the Barrier Range, and for twenty years after Sturt the explorer passed that way in 1844, the locality was known only to a few stock-owners. The discovery of gold sent men prospecting, but it was not until 1876 that silver-bearing lead ore was found at Thackeringa. A Mr. P. Green, of Wilcannia, sent a consignment to England, which was reported to contain 35 oz. of silver per ton. In 1883 further finds of silver-bearing ore were reported at Silverton and Apollyon Valley. Prospectors were encouraged by finding large masses of chloride of silver, which often contained from one-third to one-half their weight of silver, and were locally termed " slugs."

The station hands of this up-country district caught the mining fever, but when they climbed to the summit of the massive, metallic-looking outcrop, which came to be known the world over as Broken Hill, they thought they had come upon a great deposit of tin! However, a small syndicate was formed, each member paid in £70, and it was decided to sink a shaft. Unfortunately operations were begun on one of the poorest parts of the lode, and only lead ore was found. In the light of after events it is almost amusing to learn that the capital of the little syndicate became exhausted, and that the shares were at a discount. Some of the shares changed hands at figures that a few years later were multiplied many thousandfold. Nevertheless, sinking was continued, and towards the end of 1884 silver chloride was discovered at a depth of 100 feet, and after that rich ore was found in abundance. A native discovered the silver chloride in the kaolin or clay. In a short time some 46 tons of the kaolin were treated, and yielded a ton of silver, which



Broken Hill Co.

TRAVERSE CARRYING LOADED TRUCKS TO DISCHARGE.



Broken Hill Co.

WEIGHING CHARGE INTO TRUCKS FROM STORAGE-BINS.

was exhibited in Melbourne. Gold was also found in the ores, as well as lead and silver.

The magnitude and importance of this silver deposit at Broken Hill was by that time becoming apparent. The original shares were subdivided, and on August 10, 1885, the present Broken Hill Proprietary Company was floated. In the following year smelting operations were started, and since then the development of the Broken Hill mines has been rapid and uninterrupted. Eventually the lode proved to be one of the largest ever known, measuring from 10 to 200 feet thick, and extending for several miles. The mines extend along the line of lode for over two and a half miles, and at some levels it has been worked for great distances across. The deposit has been marvellously productive throughout. During the first twenty years of the history of the Broken Hill mines, no shaft had reached a depth of 2,000 feet; in fact, the productive workings in the parent mine were not below a level of 850 feet, and still, so wonderfully rich is this lode that it has produced in the period named, gold, silver, and lead to the value of £50,000,000. The dividends paid amounted to more than £12,000,000 sterling.

In the early days of the Broken Hill mines the lode was considered to be so wide that it was necessary to work it on the old English "pillar-and-stall" system in vogue in coal-mines. Solid pillars of ore were left, which it was thought could be dispensed with later. When the pillars were removed and the "square-set" system of timbering was introduced, disastrous subsidences ensued, and now all the workings are filled up as exhausted, with the exception of those required for ventilation or the conveyance of ore.

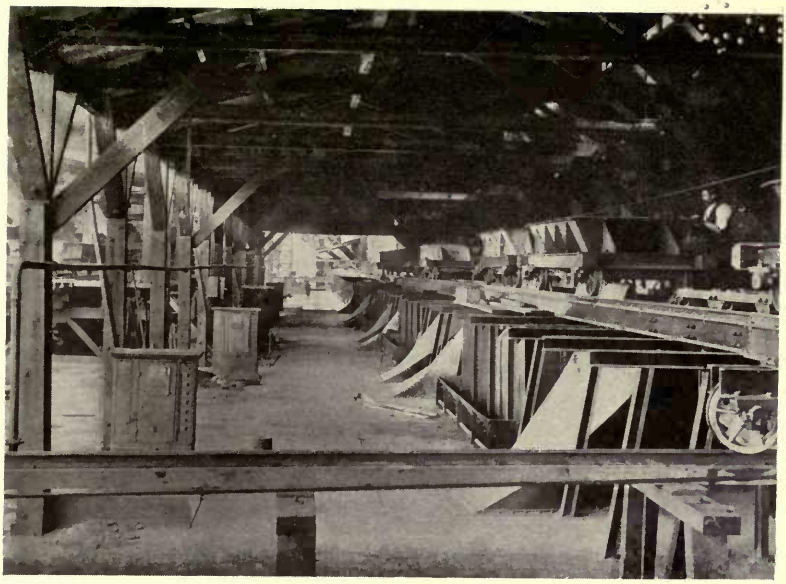
The Broken Hill mining district nowadays presents a busy scene. In addition to the complicated apparatus

at the head of each shaft for winding and sorting the ore, there are vast concentration and smelting plants. The Proprietary Mine employs two concentration plants, each capable of coping with 1,000 tons of ore per day. The problem of the profitable treatment of the sulphide ores has been practically solved.

In the early days of the boom, the air simply reeked with lead fumes; but these are now prevented from escaping. Still the absence of vegetation from the vicinity makes the fine modern town of Broken Hill look desolate. The neighbouring hills are warm-tinted but bare. The mining industry has denuded them of even their original scant covering of stunted mulga bushes and sage green salt-grass. Only calm days are enjoyable: when the wind blows, great clouds of dust are swept across this waterless country. Often the coarse sand is swept along with such violence that the glass of windows exposed to it is frosted and fretted with it.

The smelting processes which are carried on in connection with most of the silver-lead-mines of the world have for their object the concentration of the silver present in the lead. In 1833 Pattinson invented a process by which all the silver was concentrated in about 13 per cent. of the lead. The smelting is carried out in blast-furnaces of moderate size, into which a mixture of ore, fuel, and fluxes (such as limestone) is charged. The smelted lead accumulates in the hearth at the bottom of the furnace, whence it is run off at intervals. The pigs of lead are assayed and sent to be desilverized. This may be done in various ways. In 1842 Karsten found that the silver could be separated by the use of zinc. Parkes applied this practically, and by his method the silver is concentrated into about 5 per cent. of the lead, which is then cupelled.

Formerly all silver-bearing lead had to undergo



Broken Hill Co.

FEED-FLOOR OF FURNACES: TRUCKS DISCHARGING.

Broken Hill Co.

PRESSED ZINC-SILVER ALLOY ON FLOOR.

cupellation, which is a very ancient process, being referred to in the Book of Jeremiah (*circa* 600 B.C.). It consists primarily of melting the lead and oxidizing it by means of a blast of air directed on to its surface. The litharge or oxide of lead accumulates round the edge of the molten mass and is allowed to flow away. Finally, the metal that is left unoxidized is almost pure silver, and the resulting litharge can again be reduced to metallic lead. Cupellation is still used for the final separation, and as an auxiliary to other methods of concentration. The modern form of cupellation used in assaying depends upon the employment of cupels made of bone-ash, which has the curious property of absorbing the litharge and leaving the silver intact.

In this matter of cupellation we have one more exemplification of the truth of Solomon's plaint, "There is no new thing under the sun." To-day, with all the accumulated knowledge and experience of the ages, and with all the resources of modern science at our command, we have not been able materially to improve upon the ultimate process in the metallurgy of silver whereby it is separated from its base-born foster-brother lead, a process which was known even in Scriptural times.

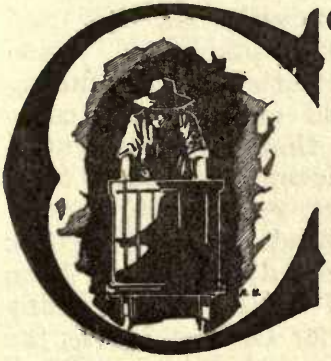
Silver has, however, fallen from its high and ancient estate as one of the aristocracy of the precious metals. In little more than three centuries after the discovery of America, its value fell from one-eleventh to one-eighteenth of that of gold. The successive adoption by Britain, Germany, and other countries of a gold standard, the heavy mintage charges on silver, and finally, the closure of the mints of the Latin Union, of India, and of the United States to the free coinage of that metal, have all combined to remove the artificial barriers to a fall in value which was an inevitable

result of the world's vastly increased output. Silver has been found in such abundance that it has practically ceased to be precious. That is the note on which the story of the silver-mines must end. Silver will always be useful, ornamental, and even valuable. It cannot be vulgarized, but it has been democratized.

COAL

CHAPTER XIV

THE FOREST PRIMEVAL



COAL is the modern genie which man has summoned from the bowels of the earth to perform the most superhuman labours. This wonderful giant, who is all energy, has spread his sombre mantle of smoke over the whole civilized world. Coal has become absolutely essential not only to our comfort and well-being, not only for the production of heat, energy, and light, but almost for our very existence under modern conditions. For without coal the industrial system of to-day would be a practical impossibility. Hardly any modern civilized country would be able to support its present population, and even if it were possible to continue the working of our highly organized industries, which is inconceivable, one cannot imagine how such dense populations could be supported without the constant supplies of food-stuffs and raw material which, thanks to coal, are now swiftly transported by sea and land. Many of the wonders and even the very existence

of our vaunted modern civilization are due to the finding of vast stores of potential energy, which owe nothing to man's foresight, but which have been handed down to us, a priceless legacy, from the ages before history began. Hidden within the unromantic exterior of a piece of coal are the materials for a story which began when order was being evolved out of chaos, and which, in view of the sequel, may be regarded as the greatest of natural miracles.

Coal as compared with many of the metals and some of the minerals, was a comparatively belated discovery on the part of man. We hear of its presence in Greece but a short period before the Christian era. True, we know now that jet, a form of cannel coal, was used on a small scale for ornaments in prehistoric times, and later by the Romans. The latter people, during their occupation of Britain, used coal for the more prosaic purpose of fuel. After that it underwent a lengthy period of desuetude. Nothing is heard of it until its rediscovery in the tenth century in Saxony and in the twelfth century in England and Belgium. From that time until the present day coal has been dug and mined continuously and on an ever-increasing scale. It was being worked in far Cathay during the visit of Marco Polo. It is being mined to-day in all parts of the world from China to Peru, and from Alaska to the Cape.

For many centuries men were content to take and use this amorphous mineralized substance known as coal without sparing a thought as to its origin. It was noticed, however, that it varied in appearance, presumably in composition, and certainly in fuel value. The brown coal which we call lignite is nearly as soft as rotten wood, while cannel and anthracite are hard, and of a brilliant black. It was not until the close of the eighteenth century that a German scientist put

forward the ingenious theory that the coal-seams were the transformed peat-bogs of ages long past

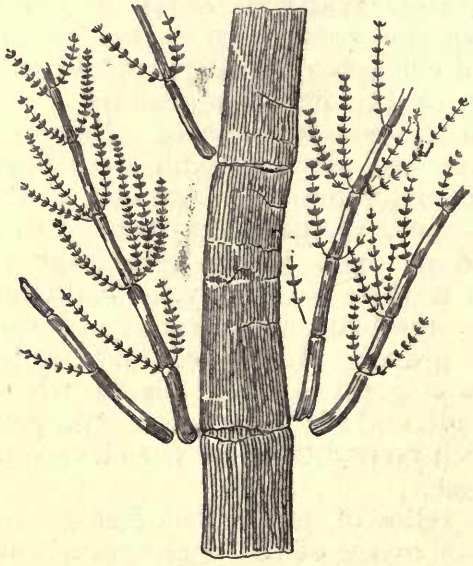
Let us try to picture for ourselves, in the light of the latest data with which science has provided us, the cycle of processes, right from the very beginning, which have resulted in the production of the various kinds of fossil fuel known as coal.

Imagine away back in the twilight of the world, flourishing in many widely scattered areas, and frequently submerged like the great river deltas of our time, dense jungles and thickets of strange and luxuriant vegetation. Some of the plants resembled those growing to-day, but on a much larger scale. Not only was the climate warmer and more equable over large areas, but the phenomenally luxuriant growth of the vegetation was due probably to the atmosphere at that time having contained a much larger percentage of carbonic acid gas than is the case to-day. This dense and heavy atmosphere was like an immense hot-house roof encouraging the growth of strange and exotic plants, the growth to a great size of plants whose descendants are but small, and of a vegetation strangely different from that which flourishes under the clear sunshine of these latter ages.

Numerous graceful relics of prehistoric fern-glades adorn the shaly roofs of many of the coal-seams, now clearly outlined in their black tracery, a real specimen of nature-printing, anon tossed and tumbled in wild profusion through the mass of mineralized vegetable matter. A very large proportion of the vegetation in this ideal forest of the Carboniferous era which I am endeavouring to bring before the mind's eye, consisted of numerous species of ferns. Although many of them resembled the existing species common in temperate climates, there were many tree-ferns such as are now found only in the tropics. The resemblance between

the fossil and the living plant is not so apparent in other groups.

Then there were dense brakes of slender, reed-like plants, standing erect and having jointed stems like bamboos. These plants, which are now known as Calamites, resemble and were indeed closely related to the *Equisetæ*, or Horse-tail as the group is popularly called—thatfamiliar denizen of marsh-lands and mere margins. Some marked differences appear, however. The stem of the largest species of Horse-tail extant rarely exceeds half an inch in thickness, while that of the Calamite often attained a diameter of five inches. The latter also grew to a greater height, sometimes as much as eight feet, and was more highly organized than the *Equisetæ*, having a bark and foliage consisting of whorls of long, narrow leaves. The Calamites have been found erect *in situ*, the root end tapering and curved towards the main axis.



CALAMITES.

Standing high above the fern glades and Calamite thickets of the prehistoric jungle were numbers of fairly tall trees, some reaching a height of 50 to 70 feet, and consisting of long straight trunks with numerous branches near the top. So faithfully have

their remains been preserved that palæobotanists can tell at once that despite their great size they are the fossil representatives of the Lycopodium or club mosses, those delicate little fern-like mosses which are familiar to many as humble members of the flora of temperate and tropical countries. They are now mostly low, creeping plants, only a few even standing erect. The tall stems of the *Lepidodendra*, as their fossil predecessors are called, were covered with scars or scales, caused by

LEPIDODENDRON.

the separation of the leaf-stalks. So numerous were these plants that in some coal measures their remains have been known to form two-thirds of the whole mass. In the vicinity of *Lepidodendra* quantities of elongated cylindrical bodies, resembling maize- or corn-cobs, or fir cones, are frequently found. These have been proved to be the fruit or catkins of the *Lepidodendra*, and are called *Lepidostrobi*.

One of the most notable plants in the forest of the

Carboniferous period was the tree-like *Sigillaria*. This plant grew to as much as 3 to 5 feet in diameter and from 30 to 60 or even 70 feet high. It was evidently to a great extent hollow, like a reed, and had a beautifully marked and fluted bark. *Sigillaria* stems of a good thickness and a few feet in height are frequently found erect, sometimes hundreds together in a comparatively small area. There are a great many varieties known of this species, no fewer than eighty-three being mentioned by Schimper in his great work.

The fossilized remains of a curious vegetable growth, called *Stigmaria*—central bosses from which great arms spread in every direction—were long supposed to represent a distinct species. They were invariably found, not in the coal itself, but in the clay underlying it, which was once the soil from which all this strange and wonderful vegetation of the Carboniferous Age sprang. Scientists like Sir C. Lyell suggested that the *Stigmaria* might be the roots of trees. Conjecture became certainty on the discovery by Mr. Binney of a *Sigillaria* and a *Stigmaria* in actual connection in the Lancashire coal-field. *Stigmaria* have since been found in British and American measures attached to *Lepidodendra*, which have been already described. This fact is held to prove the affinity of the two fossil species with each other and with the club mosses of to-day.

The *Coniferæ*, or Firs, formed a striking and distinctive genus of the vegetation of that far-off age. They were most nearly allied to the type of which the Araucarias of Norfolk Island are the most characteristic extant representatives.

Countless generations of these prehistoric plants must have grown to maturity and died in their swampy home, as is proved by the formation of deep deposits of the stems, roots, leaves, and spores, before the conditions were favourable to the beginnings of that

process which has preserved them in a transformed state until the present day. The freedom of this mass of vegetation from any admixture of sediment or foreign matter, and incidentally the fact that similar processes are going on at the present time, was made clear by the late Sir Charles Lyell,* who instanced the case of the Mississippi and what is now taking place in deltas: "The dense growth of reeds and herbage which encompasses the margins of forest-covered swamps in the valley and delta of the Mississippi is such that fluviatile waters, in passing through them, are filtered and made to clear themselves entirely before they reach the areas in which vegetable matter may accumulate for centuries, forming coal if the climate be favourable. There is no possibility of the least intermixture of earthy matter in such cases. Thus, in the large submerged tract called the 'Sunk Country,' near New Madrid, forming part of the western side of the Mississippi, erect trees have been standing ever since the year 1811–12, killed by the great earthquake of that date; lacustrine and swamp-plants have been growing there in the shallows, and several rivers have annually inundated the whole space, and yet have been unable to carry in any sediment within the outer boundaries of the morass, so dense is the marginal belt of reeds and brushwood."

From time to time in those remote ages there must have been earth movements, and the soil with this dense mass of vegetable matter underwent a gradual lowering of level so that they were submerged beneath the waters of a sea or lake. The water deposited sand or mud, and mollusca burrowed in the ooze, to be found one day embedded in the rock or shale roof of the coal-seam. But the coal-seam was as yet in its embryonic stage. Bed after bed of sediment accu-

* "Elements of Geology," by Sir C. Lyell, F.R.S., p. 393.

mulated, sometimes to the depth of a few feet, sometimes to hundreds of yards, if the continuous depression was maintained, until the water grew shallow again and circumstances favoured the formation of a proper soil and the growth once more of trees and plants, when there would be a repetition of the same process. Thus the age-long cycle of processes went on. Dense forests grew and decayed, and were submerged for countless ages, only to see the light again when brought out of their age-old prison by man. The collier in descending to his daily toil passes the records of long æons of Nature's patient alchemy.

Regarding this important question of the formation of coal there are many theories. One of the first to suggest that the coal-beds are the peat-bogs of a former age, converted first into brown coal or lignite, and afterwards into true coal, was Franz von Beroldingen, in 1778. He was supported in this theory by De Luc, and many years later by Schlotheim, Nöggerath, and Lindley and Hutton. This theory is not now generally accepted without qualification. According to the elaborate researches of the French savant Renault, the active agents in the transformation of the vegetable matter into peaty substances are fungi and bacterial ferments. Oxygen and hydrogen are expelled in the marsh gas and as water under the increasing pressure. The final product of this series of changes is lignite or brown coal. The ultimate transformation of the peaty substances into true coal is probably due to geological causes and the chemical and physical processes, such as heat and pressure, similar to those which have converted sediments into rock. The variation in the composition of the coal-seams in different parts of the same basin is attributed to metamorphism due to subterranean heat, earth movements, and so on. According to L. Lemière, however, the differences are

mainly original, the denser varieties, such as anthracite, being composed of plant substance which has been more completely broken up and deprived of its perishable constituents before submergence. The so-called bituminous coals are for the most part composed of the spores and spore cases of the *Lepidodendra*. Under the microscope a piece of such coal is seen to be composed almost entirely of the minute rounded bodies of the spores, which consist in their turn of resinous matter.

The most remarkable feature of the vegetation of the Coal or Carboniferous Age is its uniformity over a large portion of the earth's surface. The principal species of this epoch, already mentioned, are to be found alike in Europe and North America. Many of them occur in South America, South Africa, and Australia, and even at Melville Island, in latitude 76° N., similar genera are found.

CHAPTER XV

COALS AND COLLIERS OF YESTER-YEAR

HEN we endeavour to trace the beginning of the use of coal we find that its existence and usefulness first began to be realized about the time of Alexander the Great. The smiths and metal-workers of ancient Greece early discovered the suitability of coal for their primitive furnaces. In his treatise on stones, written about 300 B.C., Theophrastus, a pupil of Aristotle, mentions earthy stones found in Liguria and in Elis in Greece, which kindled and burned just like charcoal. In fact the same name *anthraces* (or charcoal) was applied to the mineral as to the older fuel which it so much resembled. Apart, however, from this reference to the use of coal by the artificers of Liguria and Elis, and possibly those of Etruria, to one of whose chiefs Macaulay refers in his "Lays of Ancient Rome" as

> "Seius, whose eight hundred slaves
> Sicken in Ilva's mines"—

there is scant trace of the use of mineral fuel in ancient times by any of the races living on or near the Mediterranean littoral.

Pliny and others mention the use of *gagates* or jet (a form of cannel coal) for ornaments, and it is more than probable that this black, shiny substance was used for that purpose at a very remote period and over a wide area. An instance of such an ornament being found beneath the gravel of an ancient raised sea-beach at Dundonald in the west of Scotland is cited by Sir Charles Lyell.* Similar ornaments have also been found at Angerton in Northumberland, along with flint knives supposed to have belonged to the period about 600 B.C.

Despite the reported finding of flint implements close to outcropping coal-seams, it is highly improbable that coal was used for fuel in pre-Roman Britain. It is almost inconceivable that a hunting, nomadic, or pastoral people with a plentiful supply of wood fuel for their simple needs, would or could, with their primitive implements, procure supplies of mineral fuel.

The Romans, however, appear to have made use of coal during their occupation of Britain. Dr. Bruce tells us that coal ashes have been found in nearly all, and coal itself in some of the stations on the line of the wall of Hadrian.† Coal was undoubtedly used both for heating the hypocausts or heating chambers of baths and houses, and for smelting iron. Various writers refer to traces of coal having been found among Roman remains at Lanchester, Manchester, Wroxeter (Uriconium), and other places, particularly in Northumberland and Durham. Solinus, in his "Collection of Things Memorable," writing of the perpetual fires kept

* "Antiquity of Man," p. 61, ed. 1873.
† "Roman Wall," 3rd ed. p. 93.

burning in the temple of Minerva at Aquæ Solis (the ancient Bath) notes that instead of the usual white ashes there is a residue of stony balls (*globos saxeos*). Coal ashes were new to him.

Taken at its maximum, the use of coal in Roman times was comparatively trifling, and with the fall of the power of Rome even that little ceased. In Britain, as elsewhere, people had little need of it. Their requirements were few and simple, and the abundance of timber in the virgin forests provided an endless supply of fuel. The Anglo-Saxons, who entered Britain on the heels of the Romans, knew nothing of coal. Wood and peat sufficed for their requirements in the way of fuel, and nothing more is heard of mineral fuel until after the lapse of many centuries.

The earliest date to which the systematic digging of coal can be traced is the tenth century, when it is said that the coal-fields of Zwickau, Saxony, began to be worked. The mineral can hardly have been dug at so early a date in Britain, as it is not mentioned in the Domesday Book (1085), although lead and iron mining are both referred to. There are some references to coal in the "Boldon Buke," a detailed survey of the See of Durham, made in 1183. But there is no means of determining with any degree of certainty whether the coal referred to was charcoal or the mineral fuel with which we are so familiar nowadays.

The story of coal and coal-mining is based on more reliable data when we reach the close of the twelfth century. The discovery of coal in Belgium was, according to the most recent researches, made prior to the year 1113, when it is recorded coal was worked on the Worm coal-field, on the confines of Belgium and Germany. In Scotland the records of Holyrood and Newbattle abbeys afford evidence that coal was being dug both at Carriden in Linlithgow and at Preston in

East Lothian before the end of the reign of William the Lion, or about the year 1200.

There is ample evidence that early in the thirteenth century coal had become more widely known and used in this and some other countries. In England, curiously enough, it was not in the district afterwards inseparably associated with coal—the classic "coaly Tine" of Milton—that the finding of the mineral is first recorded. The nascent beginnings of the coal industry are to be found farther north, along the Northumbrian coast. There the turbulent waves washed from outcropping seams, lumps of the black mineral, which were found strewn along the shore. These strange black stones, which were at first thought to be a product of the sea itself, were, not unnaturally, given the name of "sea-cole." The earliest mention of it occurs in a grant of land near Blyth to the monks of Newminster Abbey by one Adam de Camhouse about the year 1236. It is significant that no reference is made in this charter to mining or digging. The monks were simply to *take* the coal.

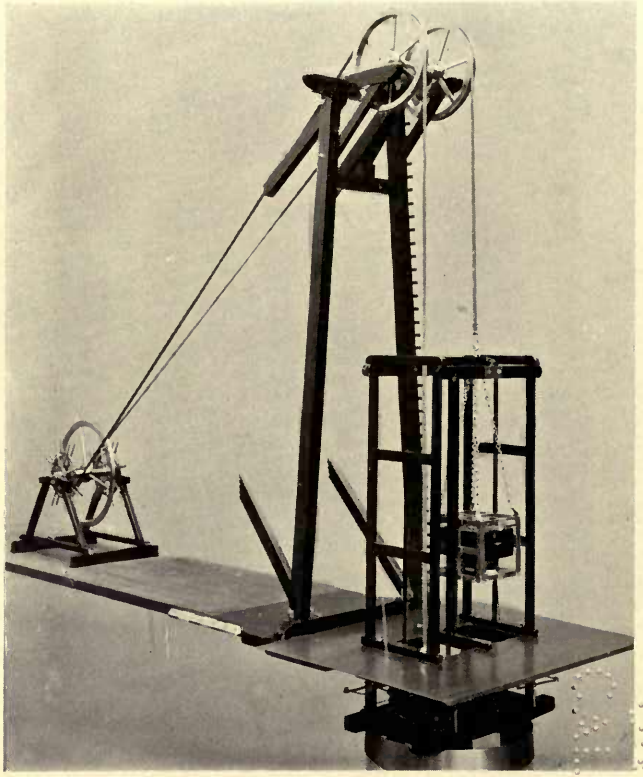
The historic connection between coals and Newcastle, which has become proverbial, dates from about the middle of the thirteenth century. A good deal of our information as to the early development of coal-mining about the lower reaches of the Tyne is provided by the records of the struggle on the part of the successive Bishops of Durham and Priors of Tynemouth to maintain their ancient rights to trade freely on the Tyne, against what they regarded as the unjust aggression of the townsmen of Newcastle. The latter, after the incorporation of their town as a royal burgh by King John in 1213, claimed an exclusive monopoly of the traffic on the river. The contest between the burgesses and the prelates—the latter frequently seeking the intervention of the law—continued with varying

results for several centuries. From the earlier records of this sorry business, one fact stands out clearly—that the monks of Tynemouth, the interesting and picturesque ruins of whose priory still adorn the northern heights at the mouth of the Tyne, were among the first to have coals dug in that district.

But so little importance was for a time attached to this hitherto valueless mineral, that up to the beginning of the fourteenth century even the very fundamental question of ownership had not been settled. No claim was made by the Crown to coal in the lands of subjects, but in 1303 the Bishop of Durham, who as a Count Palatine was endowed with quasi-royal prerogatives, conceded the right to " take mine of coal and of iron " to the " Men of the Franchise of Durham." In the record of this concession the word " mine " was used in the sense of ore or mineral, and not in its later application, meaning the place where the mineral was procured. The dual use of the word mine appears to be traceable to the Norman-French of the later fourteenth century, in which the meaning was often obscure. In Latin the distinction was always preserved, the two words *mina* and *minaria* (later *minera*)—which might be translated as mine and " minery "—always being used.

Coal was found and digging proceeded on a limited scale in different parts of the country during the thirteenth century, notably in the Forest of Dean—where iron had been mined from very ancient times—in Staffordshire, and in Lancashire. In the last-named case we have it on good authority that the monks of Bolton Abbey procured the " sea-coal " for their forge from Colne. Records concerning the use of coal during the thirteenth century are scanty. It was employed as fuel chiefly by smiths and lime-burners. Its domestic use was limited, although we find that Queen Eleanor,

Model of Pit-head Gear.



Shaft and Cages (a Model of 1835).

staying in Nottingham during the absence of her husband Henry III. in Wales, found the smoke of the sea-coal so disagreeable that she was unable to remain.*

Nor was this the only mention of the smoke nuisance, even in those early days. The coal trade between London and the North was steadily growing. Towards the end of the reign of Edward I., sea-coal was being used as fuel by brewers, dyers, and others, instead of wood. But the Londoners of those days were unaccustomed to coal smoke. In 1306, on petition by Parliament, King Edward I., according to Stowe, " by proclamation, prohibyted the burneing of sea-coale in London and the suburbs, to avoid the sulferous smoke and savour of the firing ; and in the same proclamation commanded all persons to make their fires of wood." The increasing scarcity of wood, however, was destined before very long to make this proclamation a dead letter. The introduction of the use of chimneys, which may be dated about the fourteenth century, also encouraged and facilitated the use of coal as fuel, which had been attended with unpleasant results in the open fireplaces of earlier days.

Coal at this period was procured by the most primitive methods. Supplies were at first obtained from the outcrops or on the weathered edges of coal-beds. The next step would be to remove the surface earth from above a section of the seam and to excavate the coal by open-cast or quarry work. Another early system of working coal-beds was by sinking shallow pits, which were widened out at the bottom and were called " bell " or " beehive " pits. These bell-pits may be considered as representing the transitional stage between digging or quarrying and mining proper. These infant pits have been found in many different parts of the kingdom. The outcroppings rapidly be-

* Nichol's " Leicester," vol. I. p. 143.

came exhausted, however, and the open workings became impracticable and dangerous beyond a certain depth. Underground workings had therefore to be resorted to, and this marks the beginnings of coal-mining in the proper sense of the term.

Under these changing conditions the custom of letting coal on lease had its beginnings. In return for the concession of the right of working the coal for a limited period, the lessee paid a rent to the owner of the land, and undertook at his own cost all the operations necessary for " winning " or extracting the coal.

The earlier forms of subterranean workings at the best consisted of adits, galleries, or levels, known as " day holes," driven in from the hillside, and serving both for working and drainage. By the middle of the fourteenth century even this arrangement was beginning to be found inadequate in many localities, and a more highly developed phase of coal-mining was entered upon. In order to reach less easily accessible seams, vertical pits were sunk. But to carry off the water—the miners' first great enemy—adits or horizontal tunnels had to be cut between the bottom of the pit and the nearest valley or ravine. This arrangement, generally called the " pit and adit " system, was simple and effective, and was the one in general use so long as coal-mining was carried on above the free or natural drainage level.

The lot of the miners in these primitive pits can hardly have been a very happy one, as there is ample evidence that they worked under conditions of compulsory labour, and for centuries were little more than serfs. Thus about the year 1373 or 1374 we find that John de Delgrave and Nicholas Cook were appointed commissioners to seize workmen and coal-bearers for the mines of Whickham and Gateshead. This course may have been adopted on account of the scarcity of

labour after the Great Plague, but it was by no means unprecedented nor is it the last we hear of such a state of affairs. Even so late as 1565 Queen Elizabeth, in a licence to dig for minerals,* gave power to impress workmen, wagons, and horses. But this state of things soon came to an end, and the last serf was manumitted in 1574. Probably the latest proposal to employ forced labour in the mines of England and Wales was made in the following century by Lord Bacon, who advocated the employment of felons in working abandoned mines; and held out a prospect of great treasures being thus obtained out of what he cynically describes as "a promiscuous chaos of drowned minerals and condemned men." The lifelong bond had already given place to the yearly bond in the northern coal-fields. In Scotland, however, the colliers were bound to the soil or the mine until the latter part of the eighteenth century.

Labour at this period was cheap and generally compulsory, and most of the work of the coal-mines was performed by manual workers. By the "bearing system," a degrading method of carrying coals out of the pits, the fuel was borne on the backs of men and boys, and even women and girls. This practice was continued at some of the pits in the east of Scotland until the eighteenth century.

The mining appliances were still few and simple, but were rapidly improved upon. Barrows soon came into use, and the terms "barrow-man" and "barrow-way" were handed down through the centuries and are still in use in some of the older mining districts in the North of England. Simultaneously with the sinking of the vertical pits, the windlass, with the necessary ropes and "scopes," was pressed into service. Whether these scopes or scoops were the precursors of the later

* "State Papers," Dom. 1547–80, vol. XXXVII. 44.

tubs, or of the " skips " used in winding coal to the surface, is a moot point. The " corf," a circular basket made of hazel twigs, was also largely used in hoisting coals out of the pit.

As for the method of conveyance of the coal from the pit-head to the " staith " or landing stage, where it was put on board the " keel," the Tyne collier vessel of those days, we have no very definite data. In all probability it was carried by labourers, but in the case of the more distant mines, pack-horses, and possibly carts or wains, were employed.

During the fifteenth century coal was increasingly used for domestic purposes near the coal-fields, in the coastwise towns, and even in London. Shakespeare in his " Henry IV." depicts Mrs. Quickly, hostess of the Boar's Head Tavern in Eastcheap, as reminding Falstaff of his promise to marry her, made, she asserts, " sitting in my dolphin chamber, at the round table, by a sea-coal fire." The mineral fuel began to be used too for the evaporation of sea-water and the manufacture of salt.

Towards the end of the century we first hear of water being raised from a coal-pit by means of a pump, proof that the coal was being worked below the level of free or natural drainage: so that we see that coal-mining, having passed through the " day-hole " and " pit and adit " stages, had by this time entered upon the third phase of its history, marked by the fact that both coal and water were raised to the surface by primitive machinery. There are, too, references in leases of the period which point to the leaving of pillars of coal in the mine to prevent the roof subsiding. In all these various phases we can already trace the beginnings of the proper systematic mining of coal according to modern ideas.

Although, as we have seen, coal had come into

use to a certain extent, England was, even so late as the middle of the sixteenth century, really a wood-burning country. Right up to the end of Queen Elizabeth's reign there was a good deal of prejudice against the use of coal, headed by the Queen herself. But the failure of the timber supply rendered a supply of some other fuel imperative, while the building of proper fireplaces made the use of sea-coal, as it was called, not only possible but pleasant. In fact, so rapidly did the demand for coal for household use increase about this time that Grey, the earliest historian of Newcastle, dates the real beginning of the coal trade at about the year 1570. With the accession of James I. to the English throne the hostility to the use of coal may be said to have disappeared. Coal had been used by James and his ancestors in Scotland for generations, and it is said that it was owing to the coal smoke that pervaded the atmosphere of Edinburgh that the city obtained its well-known nickname of "Auld Reekie" (Old Smoky).

The term "sea-coal," as Leland observes, was originally applied to coals found upon the sea-shore, but later writers, for example Dr. Kaye, the founder of Caius College, Cambridge, attribute the name to the fact that the supply of distant places such as London was sent by sea.

This Dr. Kaye was also one of the first of English writers to mention the noxious gases present in some coal-mines, "the unwholesome vapour whereof," he wrote, "is so pernicious to the hired labourers that it would immediately destroy them if they did not get out of the way as soon as the flame of their lamps becomes blue and is consumed." Out of the general ignorance concerning the nature and origin of these gases had sprung absurd legends attributing them to super-natural agency. In Germany during the Middle Ages

they were ascribed to the agency of subterranean demons, even Agricola referring to *animantibus subterraneis*. These gases were in England afterwards classified as "fire-damp" and "choke-damp." The word "damp" was derived from the German *dampf* (vapour or fog), a term doubtless introduced by German miners who came over to this country.

When Leland made his famous journey through England, numerous collieries were at work in various parts of the country. He referred particularly to those about Wakefield, Pontefract, and Rotherham in Yorkshire, Wigan in Lancashire, and Wednesbury and Walsall in Staffordshire.

That coal-mining was also an important industry in South Wales at that time we learn from a History of Pembrokeshire written by one George Owen in 1602, but only published in 1796 in the "Cambrian Register." From this interesting contemporary record it is apparent that "coal-bearing" had been abolished. We are told, too, that the pits were only sunk to depths varying from 70 to 120 feet, that they were drained by adits, and that gas, probably choke-damp, was a source of trouble to the miners.

Even at this early period there were some fears of the impending exhaustion of the coal supply. Sir George Selby informed Parliament in 1610 that "the coal-mines at Newcastle would not hold out the term of their lease of twenty-one years." This extremely conservative estimate was obviously based on the idea that it was impossible to work the mines below a certain level on account of the inflow of water. Such pessimism was not unnatural in view of the numerous instances of flooded pits and drowned miners which were recorded about that time. The coal-owners, where possible, constructed long adits, but many pits were permanently flooded and had to be abandoned. At the best, primi-

MINE-SURVEYING IN THE MIDDLE AGES

tive methods of winning and transporting the coal involved excessive labour and expense, and profits were slight.

Grey, in his "Chorographia; or a Survey of Newcastle-upon-Tyne," published in 1649, wrote:

"Some south gentlemen hath upon great hope of benefit come into this country to hazard their monies in coale pits. Master Beamont, a gentleman of great ingenuity and rare parts, adventured into our mines with his thirty thousand pounds; who brought with him many rare engines not known then in these parts; as the art to boore with iron rods to try the deepnesse and thicknesse of the coal; rare engines to draw the water out of the pits; waggons with one horse to carry down coals from the pits to the stathes, to the river, etc. Within few years he consumed all his money, and," concludes the chronicler significantly, "rode home upon his light horse." *

In all probability these devices, which were such novelties in the North of England, were suggested by those in use at the German metalliferous mines, which were fitted with engines for raising water as described by Agricola in his *De Re Metallica*. Boring, too, is heard of in different parts of England at this time, and was rapidly adopted by coal-owners and those in quest of coal-seams.

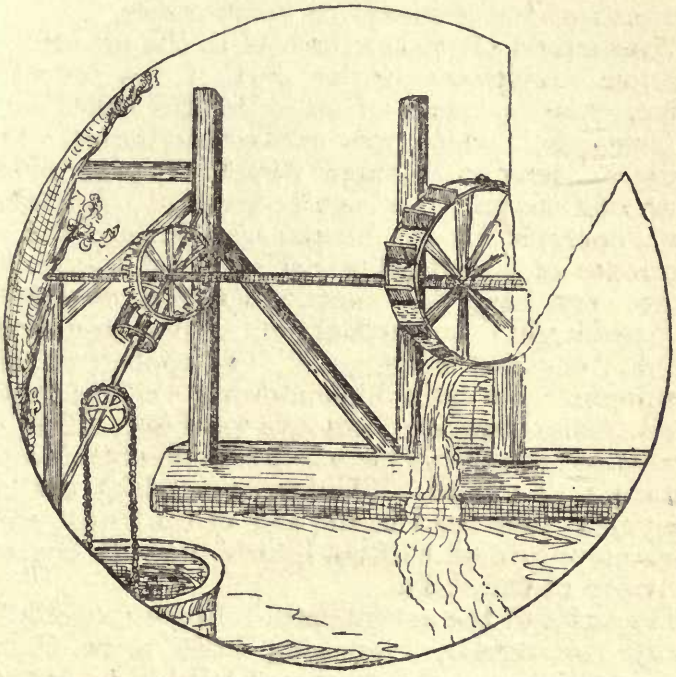
Another notable advance which was made in the coal industry during the seventeenth century was the construction of railways, or as they were then called wagon-ways, between the pit-mouths and the staithes. The germ of the railway was of course the barrow-way, a single plank. The early German railways consisted of two planks placed close together, as depicted by Agricola,† and adapted for small four-wheeled wagons,

* "Annals of Coal Mining," R. L. Galloway, Ch. XV. pp. 151–2.

† *De Re Metallica*, Lib. VI.

called *hunds*, fitted with a guiding-pin. The early type of Tyneside waggons were fitted with flanged wheels made of wood.

The raising of the water from the pits was, however, the pressing coal-mining problem of the period. Most



PUMPING MACHINE OF 1684. WELSH COAL-MINE.
From a contemporary MS.

of the workings were situated in the belt of watery strata, which usually extends down to a depth of from 300 to 600 feet, and the drainage of the mines seemed an almost insuperable difficulty. Many devices were tried, but the chain pump was the one most generally used.

Briefly, it consisted of an endless chain fitted with buckets which brought water up out of the shaft and discharged it at the surface. It was found to be impracticable to apply this system to any great depth, and even a "lift" of 240 feet had to be worked in two or three stages. These chain pumps were operated by means of water-wheels or horse-power.

The method of raising the coal to the pit-head most in vogue during the earlier part of the seventeenth century was by means of an apparatus called a "cog and rung gin," which was worked by horses. It was simply a drum or enlarged windlass placed over the mouth of the pit. The cogs or teeth of the horizontal wheel, operated by the horses, worked into the rungs or grooves of a vertical wheel attached to the drum. Before very long this contrivance was displaced by the "whim gin" or vertical gin, a great improvement on the "cog and rung gin." The rope-drum of the "whim-gin" was built high up on a vertical axis and placed some distance from the pit-head. The ropes were carried on pulleys placed on a timber frame directly over the pit's mouth. The levers to which the horses were yoked were fixed to the axis of the drum, and the horses moved round without interfering with operations at the top of the shaft.

The shaft of the seventeenth-century coal-mine was usually rectangular, measuring little more than six feet each way, and was timbered with oak spars or fir balks. It was found that water could be kept out of the shaft by the use of watertight frames formed of wooden staves like those of a barrel, and thence termed "tubbing." By this means pits were sunk to a depth of 300 or even 400 feet.

The underground workings consisted of two sets of excavations driven in the coal-seam at right angles to each other. The main excavations, called "bords,"

from which the coal was obtained, were driven across the seam. In Scotland the miner's working place was called the " room," in other places the " stall." The headways or passages for haulage and ventilation ran, as has been said, at right angles. The rationale of this system was that a certain quantity of the coal was taken out, but large square pillars of the mineral were left to support the strata above. The principle of this method persists to the present day, but the pillars are ultimately removed. When they were left intact barely half the coal was taken out of the seam.

The ventilation of the old-time mines was mostly left to take care of itself, and was dependent upon the natural circulation of the air between the pit and the adit, or between the shafts if there were more than one. Dr. Plot's " Staffordshire " contains one of the earliest notices of the employment of fire to produce an artificial circulation of air in English mines. Fire had already begun to be employed to ventilate coal-mines in Belgium.

With the closing years of the seventeenth century came several inventions intended to raise water by means of fire, the first step in the direction of utilizing the power of steam. The most notable of these devices was that which Captain Savery, the patentee, called an invention for raising water " by the impellent force of fire, which will be of great use for draining mines, etc." This engine, which was really a device combining suction and pressure by steam, was of very limited capabilities and did not fulfil the inventor's sanguine expectations.

The Shropshire coal-field was one of the first in which railways were employed in connection with the mines. The pits were not so large or deep as those in the North of England, but in this district a striking and distinctive method of winning the coal, known as the

"long-wall" system, was first evolved. By this process—which bears some resemblance to the mode of working a metalliferous mine—the whole seam or vein of coal is excavated as the workings advance. The space previously occupied by the coal (now called the "gob" or "goaf") is filled with stones and refuse on which the superincumbent strata settles down. The necessary roads or passages through the old workings are kept open by means of strong packs or walls of stone, several yards thick, which are built on each side. As these are gradually crushed by the tremendous weight of the subsiding rock, the roof or floor is cut away to provide the necessary passages until sometimes they are mere tunnels cut through the rock.

The Cumberland coal-field had reached a fair degree of development during the seventeenth century, the principal pits being at Whitehaven and near St. Bees. At Whitehaven, the land having passed into the hands of the Lowther family, Sir John of that ilk exhibited considerable energy and enterprise in draining and working the coal-seams of the district. Other mine-owners began to ship coal at Whitehaven, which secured a share of the Dublin coal trade. The growth of the coal-mining industry in Cumberland was thereafter very rapid. In the year 1709 there were seven pits at work about Whitehaven. The wages book of one of the Lowther collieries, dated 1675, is still extant at Whitehaven Castle, from which it appears that the work-people were paid by the day at the following rates: viz. "haggers" (coal-hewers), tenpence per day; trailers or putters, eightpence; winders, eightpence; and corvers or basket-makers, one shilling per diem.

Until the beginning of the eighteenth century, miners, when it became necessary to cut through solid rock, had to have recourse to the most primitive methods. When hand labour was insufficient, the only alternative was

Wigan Coal and Iron Co.

PIT SCREENS: SCREENING AND CLEANING FUEL.

DUKE UNIVERSITY
LIBRARIES

the ancient one of rendering the rock more friable by heating it and then suddenly cooling it with water. About the year 1719, however, the method of blasting by means of gunpowder was introduced from Germany, where it was being used in the metal-mines.

By this time many of the collieries in the North of England had penetrated beneath the watery strata and had reached a depth of upwards of 400 feet. There the miners found their deadly enemy fire-damp frequently present in considerable quantities, and then began the long series of colliery explosions which have ever since been such a tragic feature of the story of the coal-mines. As pits grew deeper and more expensive, the underground workings grew more extensive, and consequently less efficiently ventilated. Then again, as the collieries increased in size, the number of miners was also augmented. So that many factors combined to emphasize the danger of the subtle enemy which the coal-miners had to meet. The first great colliery explosion took place on October 3 or 4, 1705, at a pit at Gateshead, and over thirty lives were lost. Three years later, at Chester-le-Street, there was another terrible explosion, by which no fewer than sixty-nine colliers were killed.

One of the chief factors in the development of the coal-mining industry, which was so marked during the eighteenth century, was the invention of the steam-engine—an event which was one of the most important in the annals of coal-mining, as of industry in general. It is not within the scope of this work even to summarize the successive stages in the evolution of the steam-engine, from the contrivance of Savery and the essays of Papin, to the ingenious engines of Newcomen and Watt. To Newcomen belongs the honour of first putting the dreams of the scientists into practical form and perfecting the earliest self-acting steam-engine.

As I have already mentioned, the pumping of coal-mines was one of the pressing problems of the period, and it was significant that the first Newcomen engine was erected at a pit in Staffordshire in 1712. This application of the steam-engine to mine-pumping enabled new seams to be worked, as well as allowing old ones that had been flooded to be re-opened, and permitting of deeper sinking.

The perfection, about the year 1735, of a method of smelting iron by means of coal—a problem that had long defied solution, was due to the efforts of Mr. Abraham Darby of Coalbrookdale. It was one of the triumphs of the eighteenth century, and marked the beginning of a peaceful revolution. In no other industry were its benefits more quickly felt than in coal-mining. Iron cylinders were cast for the engines, iron wheels for the waggons, iron rails, and so on. The coal and iron trades were destined henceforth to be mutually interdependent—Pluto and Vulcan became allies in the forward march of civilization and the industrial conquest of the world.

The deepening of the mines, rendered feasible by the advent of the steam-pump, involved a larger capital outlay and necessitated a larger output if the mine were to be remunerative. Improvements were called for in every department of colliery engineering, and most imperatively in the hauling of coal underground and the winding of it to the surface. Many attempts were made to adapt the steam-engine to the winding of coal and the ventilation as well as the pumping of the mine, but without any great success until the ingenuity of Watt enabled him to improve upon the Newcomen mechanism, and produce the double-acting engine.

The repeated explosions which took place in the fiery pits of the North turned the attention of colliery owners and managers to the efficient ventilation and

safer lighting of the pits. The system of "coursing the air," or causing it, by means of stoppings and doorways, to traverse every part of the workings, was introduced into the Newcastle district about 1765, but was previously in use in Cumberland.

An ingenious attempt to secure the safe lighting of fiery mines was invented by Mr. Spedding, of Whitehaven, about the same time. It was known as the "steel mill," and consisted of a thin disc of steel which was made to revolve quickly by means of a handle and wheel and pinion gear. A piece of flint was applied to the edge of the rotating disc, and a continuous stream of sparks resulted. By the dim and uncertain light of the stream of sparks five or six miners were supposed to be able to carry on their work. The use of the steel mill in a fiery mine was at first thought to be quite safe, but this was soon proved to be a mistaken idea.

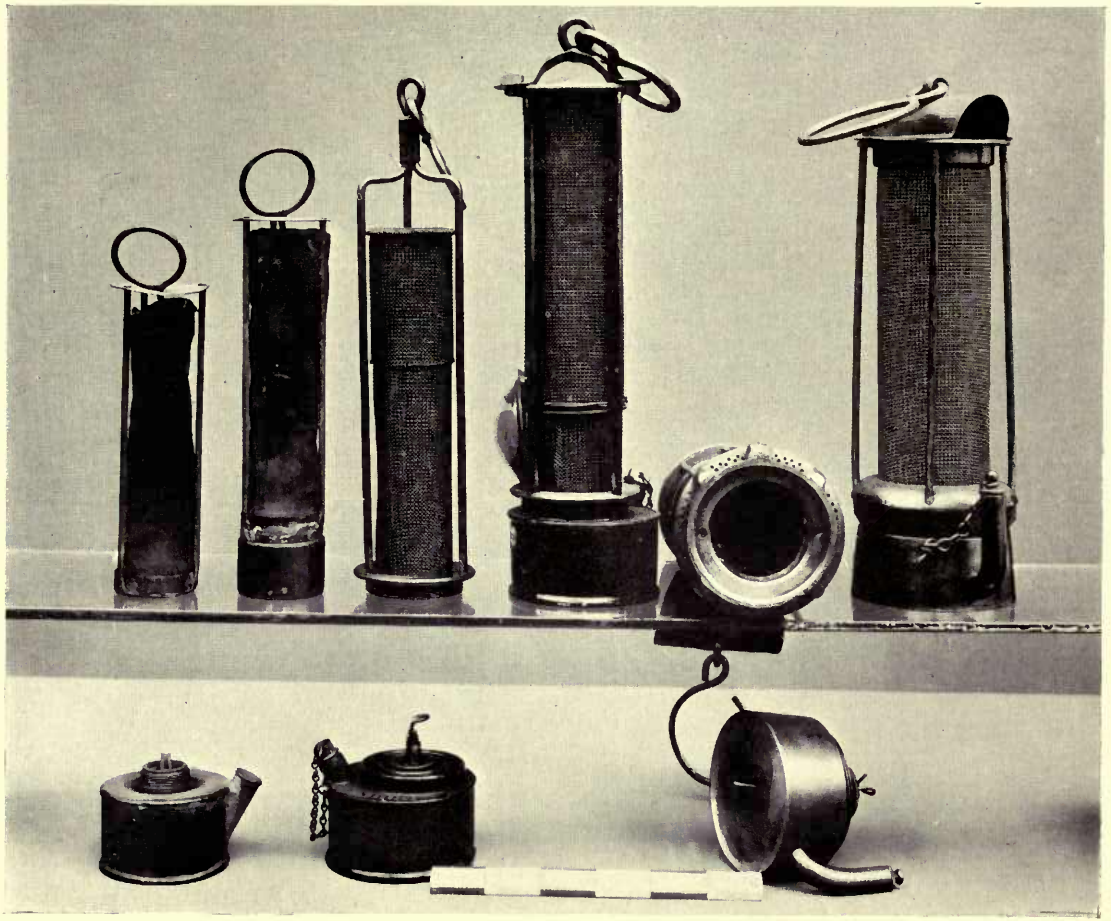
Looking back upon the eighteenth century as a whole it will be evident that it was a period of important improvements in coal-mining. The most striking innovations were the adoption of the steam-engine for raising water from the mines, the use of gunpowder for blasting, the artificial ventilation of workings by means of fire, and the "coursing" of the air through the whole mine to prevent the accumulation of gas. Horses were employed in the underground haulage of coal, and railways and four-wheeled wagons were displacing the barrows and sledges previously utilized. The close of the century was marked by the general displacement of wood in favour of iron in the making of railways, and the application of the steam-engine to the winding or raising of coal from the pits. The cutting of canals, in which the Duke of Bridgewater was the pioneer, was also an indirect result of the increasing demand for coal and the necessity for cheap transport in bulk.

With the beginning of the nineteenth century may be said to have come the dawn of the age of coal. Its previous development was as nothing to that which it was destined to attain. Without coal it is impossible to imagine how the stupendous industrial development of the nineteenth century could have been achieved. Without coal it is more than unlikely that the steam-engine would ever have been widely used. Coal provided the fuel to make and then to propel Trevithick's and, later, George Stephenson's locomotives, which in their turn helped to distribute the coal to the myriad fires and furnaces of the kingdom.

But so far as coal-mining itself was concerned, although the extended use of the steam-engine practically revolutionized the working of the mine, and improvements were introduced into almost every department, by far the most important event of the early nineteenth century to the thousands of colliers who daily risked their lives in the fiery mines was the invention of the safety-lamp.

Dr. Clanny of Sunderland was one of the first to concentrate his attention on devising some means of lighting which would be safe to use in a fiery mine. He succeeded about the year 1812 in constructing a lamp in which the air supply, before and after combustion, had to pass through water. Theoretically the idea was perfect, but the lamp was clumsy in construction and never came into very general use.

Repeated devastating colliery explosions, causing a loss in the aggregate of a terribly large number of lives, had demonstrated the deadly dangers of fiery mines. At last the terrible explosion at Felling Colliery, Northumberland, in 1812, focussed public attention on the matter, and a society for preventing accidents in coal-mines was formed. It was soon decided that the perfection of a safe method of lighting was the best



MINERS' SAFETY LAMPS.

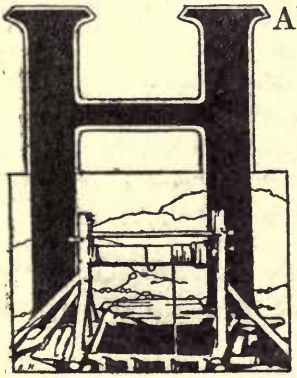
UNIVERSITY OF MARYLAND

way to avoid igniting the explosive fire-damp. Sir Humphry Davy was consulted. He at once concerned himself in the matter, made a series of interesting experiments, and visited several collieries. The progress of his investigations was rapid, brilliant, and successful, culminating in 1815 in the evolution of the well-known lamp that bears the distinguished scientist's name. The principle of this famous lamp, in which the flame burns inside a hood or cylinder of wire gauze, is based upon the fact that flame will not pass through fine wire gauze unless the latter becomes overheated. The gauze thus prevents the lamp from igniting any gas outside the cylinder, unless the flame is forced against the gauze and makes it red-hot. For this latter reason the Davy lamp is not safe to use in a rapid current of air, and the speed of the ventilating currents in modern mines has caused the original form of Davy lamp to be superseded.

And now, having traced briefly the evolution of coal-mining, let me turn to the tale of the distribution of the mineral itself.

CHAPTER XVI

THE WORLD'S COAL-FIELDS



HAVING sketched the early history of the knowledge and use of coal, and of the origin and growth of coal-mining in this country, which has been in many respects typical of its progress in other countries, I come now to consider briefly the principal coal-fields of the world as we know them to-day.

Coal, of all substances mined from the bowels of the earth, is the most widely distributed, and is produced in larger quantities than any other mineral commodity. Of the principal classes of coal, that known as bituminous is perhaps the commonest. It is, generally speaking, black in colour, often waxy in lustre, and contains from 73 to 90 per cent. of carbon, with a varying amount of ash. The term bituminous is something of a misnomer, as coal contains no mineral pitch, but it softens somewhat in burning, and blazes like pitch. Bituminous coal is classified according to its properties as free-burning, steam or smokeless coal, and non-caking coal. These are valued chiefly for engine furnace and smelting purposes. The caking coals are those which tend to fuse partially when

burning. The " household " coals are usually of this variety, and freedom from ash is a great recommendation. The " smalls " are frequently turned into coke.

Cannel is often considered to be a variety of bituminous coal, with the seams of which it is frequently found in parallel layers. But it is in many ways very different from ordinary coal. It is dull in lustre, breaks with a flat, conchoidal fracture, is not made up, like ordinary coal, of flat layers or laminæ, and does not soil the fingers. Its name, said to be derived from " candle," is supposed to relate to the readiness with which it lights and gives off a steady flame. Some varieties crackle loudly when burning; hence, no doubt, the name of " parrot " coal which is given to them in Scotland. Cannel coal is very largely employed for gas-making.

Anthracite is another well-known and distinctive class of coal. It is stone-like in appearance, but has a semi-metallic lustre, contains a very high percentage of carbon, and on that account is less easy to kindle. It burns without much flame or smoke, and is for that reason largely used by the navies of the world. Anthracite is the least widely distributed of all varieties of coal. The best qualities are procured from the South Wales and Pennsylvanian coal-fields.

Brown coal or lignite lies at the other end of the scale of varieties of coal, and is in reality not a true coal at all, but forms a connecting-link between peat and coal. It is obviously formed of a mass of vegetable matter imperfectly mineralized—some kinds having the appearance of undecomposed wood—and varying in colour from brown to black. It burns easily with a smoky flame. A good deal of the lignite procured in Germany and Austria is turned into briquettes.

Beginning with the coal-fields of the United Kingdom, the oldest and most historic of British coal areas is now known as the eastern portion of the Great

Northern coal-field. It stretches from the Coquet in the north to near the Tees in the south, or for a distance of about 50 miles in length, with an average breadth of 20 miles, giving a total area of about 800 square miles. The total thickness of the measures is little more than 2,000 feet, of which the lower half contains all the most valuable seams. For some miles along the western side only a few of the lower seams are worked. Then about Newcastle and Durham we get the maximum number of workable seams; but east of a line from Tynemouth, past Houghton-le-Spring, to Bishop Auckland, the watery strata present a serious obstacle to the sinking of shafts. At one time it was thought that this marked the limit of the coal-field; but in 1826 the famous Monkwearmouth pit was commenced. After passing through 330 feet of watery strata the seams were reached at a depth of nearly 1,700 feet below sea-level. They proved to be identical with those worked at a less depth north and south of Sunderland. As the measures have a gentle inclination eastwards, it is more than likely that an extension of the field is continued beneath the bottom of the North Sea.

The Great Northern is in many respects one of the most advantageously situated of coal-fields. The measures dip at a moderate angle, and the workable seams—of which the average number in any one section may be taken as twelve—vary from 3 to 6 feet in thickness, with an aggregate of 50 feet. The coal is, generally speaking, of good quality, and the nature of the overlying strata allows of wide working-places requiring but little timbering to support the roof. On the other hand the newer pits have to be worked at great depths; the shafts have to be sunk through the troublesome watery strata; and a large amount of fire-damp is encountered. Faults and slip-dykes are

comparatively few and far between, and the whin or basaltic dykes do not derange and injure the coal-seams as they do in South Staffordshire and in Scotland. Among the ordinary faults the most notable is the great 90-fathom dyke, which displaces the strata for that distance all the way from the coast at Cullercoats, past Gosforth to Blaydon, and right away across the hills towards Carlisle.

The coal produced naturally varies in quality over such an extensive field. The best household coal, usually called Wallsend, is got in the districts between the Tyne and the Wear, between the Wear and Castle Eden, and also about Bishop Auckland. The denser white-ash steam coal is raised from seams north of the Tyne, while tender or coking coal is got from the outcropping seams on the west.

The development of the resources of the Cumberland coal-field was, as we have seen, fairly well under way in the seventeenth and eighteenth centuries. Later exploitation proved that neither the thickness of the measures nor the number of seams were equal to those of the Durham field. The quality of the coal is also inferior both for household use and for conversion into coke. Still, although the Cumberland field is comparatively small, measuring only some thirty miles by six, many of the seams are notable for their thickness and regularity. They are remarkable too from the fact that for two or three miles along the coast near Whitehaven extensive operations have been carried on to a distance of between two and three miles out under the bottom of the sea. The strata dip slightly seaward, and a succession of faults have rendered the exploration of the seams difficult and expensive. The maze of workings under the sea-bottom is reached by horizontal roads driven from several pits at a depth of from 100 to 150 fathoms. The principal seams are the

Bannock band, which varies from 6 to 10 feet thick, and the Main band, from 9 to 11 feet.

At Workington the coal was also wrought beneath the sea. The seams, however, inclined upwards towards the sea-bottom. With a strange and fatal lack of foresight they were followed too far, and in 1837 the water burst in, bringing an awful death to thirty-six poor fellows and converting the mine into a submarine catacomb for all time.

The North Midland or Yorkshire and Derbyshire coal-field is the largest continuous coal region in England, and is second only to that of South Wales in Great Britain, extending as it does in one practically unbroken expanse from Leeds to Nottingham, a distance of 65 miles. The width of the field varies from 8 to 20 miles, and the total area is computed to be 800 square miles. The thickness of the coal measures where they are most fully developed is about 3,000 feet, while the total thickness of coal contained in the sixteen seams is some 45 feet. The best-known seam is the "Top-Hard," which in Derbyshire measures from 5 to 6 feet, but on passing into Yorkshire increases until it grows into what is called the "Barnsley thick bed" of 9 feet. Other well-known seams are the "Clod" or "Black Shale" and the Kilburn of Derbyshire, and the "Silkstone" of Yorkshire. Below the Barnsley Bed the seams are wonderfully persistent.

The beds incline gently to the east, where they are overlaid by newer formations. The extension of the field in an easterly direction was first proved by the Duke of Newcastle's boldly-conceived experimental boring at Shireoak, where at a distance of five miles eastward from the hitherto recognized limits of the coal-field, the Top-Hard seam was encountered at a depth of 510 yards. The output of coal from the Yorkshire, Derbyshire, and Nottinghamshire field in

Wigan Coal and Iron Co.

PIT HEAD, CLOCK FACE COLLIERY, NEAR ST. HELENS

DUKE

1906 was sixty million tons, or nearly double that of South Wales.

The Lancashire coal-field is one of the best known of British coal-fields. Though not very extensive, the number and thickness of the seams render the field a rich and productive one. Professor Hull, who examined it for the Geological Survey, estimated the total area at 217 square miles. There are numerous faults, one with an estimated displacement of 1,000 yards forming the western boundary of the field, and another the Irwell Valley fault, with a similar downthrow, lying east of Manchester. The depth of the coal measures has been estimated to be something like 7,000 feet, which is generally divided into the upper or Ardwick series, containing few workable seams; the middle series (3,000 feet), containing all the more important seams with the Arley Mine coal as the base-line; and lastly, the lower or Mountain Mine series (2,000 feet).

The Mountain Mine seams are three in number, but only two of them are of workable thickness, namely, the Upper, from 14 to 16 inches thick, and the Lower or Gannister Coal, from 18 to 36 inches, some 60 or 70 yards lower. In the Middle Series some of the seams extend throughout the coal-field, though known locally under different names. Other seams, such as the famous Cannel Mine, taper off in every direction from Wigan. The Arley Mine, which is also known as the Orrell, Four Feet, Royley, and Fulledge Main Coal (Burnley), is one of the most important and widespread seams.

Between the Arley Mine and the neighbouring Ince group of coals several important seams occur, including the Wigan Nine Feet, which becomes in turn the Trencherbone of Bolton and the Roger Nine Feet of St. Helens. The Ince group of seams at Wigan comprises, in ascending order, the Seven Feet, Four Feet, and Yard seams. Between this last group and the

next important seam, a series of barren strata intervene, thick in the east but diminishing in the west. Then there is the Bradford Four Foot Seam, succeeded at intervals by a few seams, including the Charlotte and Openshaw Mines.

The total number of seams is on the average from sixteen to twenty, containing in the aggregate about 70 feet of coal. The seams are generally from 3 to 6 feet in thickness. Some of the deepest workings in the British Isles are in the Lancashire coal-field, the Pendleton Colliery, near Manchester, being worked at a total depth of 3,483 feet from the surface.

The valuable series of coal measures in North Staffordshire are estimated to extend down to a depth of 5,000 feet. The two principal series of coal-bearing strata are the Pottery coal and ironstone measures, containing several seams of inferior coal, and the lower thick measures, which include the chief furnace coals from the Ash to the Winpenny, in all seventeen or eighteen workable seams above 2 feet in thickness. In certain portions of the field no fewer than forty seams, with a total thickness of 140 feet of coal, have been proved to exist. The North Staffordshire coal-field is bounded on the east by the outcrop at the foot of the hills, and on the south and west the measures sink beneath the great plain of new red sandstone, which stretches right away to the Welsh Marches. Geologists tell us that in all probability the coal measures continue beneath the newer strata, and developments are now being made in this direction.

Farther south lies the "Black Country" of the South Staffordshire coal-field. It is notable, not for its area, which is only about 149 square miles, or for the depth of its coal measures, but for the thickness of the main seam. The presence in the southern portions of the field, about Dudley, Bilston, and Wolverhampton,

of the Thick Coal, or Ten Yard seam, as it is called, which has a thickness greater than any other seam in the country, measuring as it does from 24 to 36 feet, was one of the sources of the unusual richness and productivity of this field. The " thick coal " is, however, being worked out, and lower seams are now being operated, while the constituent parts of the Ten Yard seam are being mined at Cannock Chase. There are small coal-fields near Nuneaton and Atherstone in Warwickshire, and near Ashby-de-la-Zouch in Leicestershire.

Crossing over the great Midland plain south-westwards towards the Severn, the traveller would reach the busy industrial district of Coalbrookdale, an area historically identified with the growth and development of the coal and iron industries. Never very rich or productive as a coal-field—the total thickness of the measures not exceeding 1,200 feet, and the thickness of coal-seams diminishing from 55 feet at Donnington southwards to 16 feet near Broseley—the old field is nearly exhausted. There are signs, however, that deeper working will reveal an extension eastward.

Commencing near Oswestry and Chirk, a narrow coal-bearing tract skirts the foot of the Welsh hills nearly all the way northwards through Ruabon and Mold to Mostyn on the shores of the Dee estuary. The seams are not numerous, but some of them are of exceptional thickness, and a bed of cannel found in recent years near Mold is of excellent quality.

The South Wales coal-field is the largest single coal area in Britain, and contains as great a vertical depth of coal measures as any in the world. The field occupies part of the counties of Monmouth, Glamorgan, and Carmarthen, and has a total area of over 900 square miles. Northwards the seams terminate suddenly in outcrops at the foot of the mountains, and southwards

the field is indented by the deep valleys of the Nedd, Afon, Ogwr, Taff, Rhymney, Ebbw, and Rhondda.

It is a remarkable fact that parts of some of the seams in the South Wales field have undergone a marked change as compared with others. Towards the east they are mostly bituminous or gaseous, and upon reaching the centre of the field, the same seams become semi-bituminous or " steam " coals, and, farther west, gradually pass off into anthracite. This is a phenomenon that it has puzzled geologists to account for. It can only be conjectured that the measures were at one time covered to a great depth (possibly 10,000 or 12,000 feet) by other strata, and consequently subjected to a high temperature. As for the variations in the metamorphism of identical seams, the intrusion of igneous rock in a molten state is put forward by some writers as an alternative solution.

In Monmouthshire the thickness of the strata is much less than in the more westerly portions of the field, the " Black Vein," the lowest seam of importance, being worked at a depth of 650 yards. The best-known seam is the Mynydd Isslwyn, a house-coal which has been, however, nearly worked out. Beneath a great thickness of " Pennant " sandstone come the furnace coal and clay iron ores which have given rise to the great iron-works at Pontypool, Ebbw Vale, and Tredegar. Farther west at Llanelly an upper series of seams occupy a narrow area running east and west, where the full thickness of the coal measures is estimated at 10,000 feet. Westward of Carmarthen Bay the thickness of the measures is again greatly reduced, and their value is discounted by the violent foldings and convolutions to which the strata have been subjected.

The north-eastern section of the coal-field is the source of the steam coal which is famous all over the world. It attains its highest fuel value combined with

smokelessness in the vicinity of Aberdare. Some of the best seams have been exhausted. From Aberdare westward to Llanelly the coal is bituminous, while along the north side of the field it changes to anthracite, and the latter variety alone is found in the seams rising northwards in Carmarthenshire.

The coal-fields of Scotland comprise nearly a dozen more or less disconnected basins in the central lowlands extending from the Firth of Forth to the borders of Ayrshire, and covering a total area of 1,680 square miles. Although in all probability originally continuous from the Ochil Hills to Ayrshire, the coal measures have been broken up by earth-movements and denudation into separate fields, chief of which are those of Ayr, Lanark, Renfrew, Dumbarton, Stirling, Linlithgow, Clackmannan, Midlothian, and Fife.

The Midlothian coal-field lies in a trough of the Pentland and Lammermuir Hills. Geologically the field is a true basin, the seams and other strata describing a semicircle. In the centre the seams are almost horizontal (Flat Coals), while near the confines of the field they are highly inclined (Edge Coals). The seams in the carboniferous limestone deteriorate in thickness and quality towards the south, and the coal-measure seams, while thicker and more numerous in the west than in the east, also taper off to the south. The chief seams in ascending order are the Seven Feet, Fifteen Feet, Nine Feet, Jewel, Diamond, Beefie, and Splint.

The Fife coal-field extends east and west, parallel to the Firth of Forth, and covers an area of about 170 square miles. To the west it joins the Alloa field. A coast section shows seventeen seams, with a total thickness of 74 feet of coal. The Dunfermline Splint is one of the best-known seams and yields an excellent house and steam coal. A large quantity of coal lies beneath the Firth of Forth ; but the amount obtainable

depends upon the character of the sea-bottom. Should this prove to be of impervious boulder clay, as at Bowness, it is calculated that the amount of coal obtainable within the three-mile limit would exceed a thousand million tons.

The Lanarkshire coal-basin is the principal coal-producing area in Scotland, and embraces the coal-fields of Glasgow, Lanark, and Linlithgow. Over 250 collieries are at work on the various seams, the most important of which are the Drumgray, Kiltongue, Virtuewell, Splint, Main, and Ell. The deepest portion of the basin is worked at Hamilton and Bothwell, and other notable colliery centres are Bellshill, Coatbridge, Airdrie, Motherwell, and Wishaw.

The well-known boghead gas-coal or Torbanehill cannel coal, which occurred irregularly and generally in thin seams, is now nearly exhausted.

Such in brief are the British coal-fields, undoubtedly the basis and still the buttress of this country's commercial and industrial supremacy.

The French coal-fields, although hardly sufficient to supply the demands of its large population and flourishing industries, are of considerable magnitude. The northern and central coal-mining districts are the most important. The former occupies a narrow zone of the Departments of the Nord and Pas de Calais, extending from Valenciennes towards Boulogne and diminishing in value towards the latter place. In this field are the great mines of Courrières, the scene of the terrible explosion and fire of 1906, the most awful colliery disaster on record.

The coal-fields of central France are chiefly notable for their small area and irregularity, and the fragmentary and unequal nature of the seams. The latter occasionally attain a great thickness, at times as much as 80 feet, but are very much broken up. Another im-

portant field is that of St. Etienne and Rive de Gier (Loire), occupying a length of 34 miles. The lower seams, one of which is of great thickness, cover an area of 60,000 acres. The upper series comprise twenty seams of from 3 to 16 feet, and covering an area of only 10,000 acres. Another remarkable coal-bed is that of the Saône-et-Loire, the chief mining centres of which are Creusot, Blanzy, Montchanin, and Epignac. The coal measures include ten seams, some of which are of unusual thickness, one at Montchanin being 130 feet! These coal-fields of central France are really basins in the older rock, so that their limitations are sharply defined.

The Belgian coal zone stretches from Mons in the west, via Charleroi and Namur, to Liége in the east, a distance of about 100 miles. This zone is divided up into several basins. The steep angle of inclination of the strata and seams—which are sharply folded and even zigzagged, particularly on the western side in Hainault—has rendered the sinking of deep shafts necessary. The Saint Henriette shaft, Cie. des Produits, Flénu, reached in 1900 a depth of 1,150 metres, or 3,773 feet.

Of the Belgian coal-basins that of Mons may be taken as typical. No fewer than 157 seams of coal are known, of which 120 are workable. The upper series of 47 seams are the *Flénu*—a species of coal burning with much flame and gas; the next group of 21 seams are coking coals; then come 29 beds of *charbon de forge;* and lastly 20 to 25 beds of *charbon sec*, or *maigre*, a dry coal burning with little flame.

Within recent years the Belgian coal-mining industry has developed rapidly, and the mines are among the best equipped in the world. The expense of deep sinking has tended to increase the area worked from a single shaft. The method of working is by a modified

kind of long-work. The quantity of coal raised per man is much less than the average English output, the difference being accounted for partly by the thinness and difficult positions of many of the seams.

Crossing the frontier into Germany, one is naturally attracted to the Saxon coal-field, not so much on account of its extent or importance as for its historic interest as the first European field to be worked during the Middle Ages. It is interesting, too, geologically, as presenting an unusually clear example of the succession of the plant growth of the coal era. The lowest seams at Zwickau consist chiefly of Sigillariæ, forming *pech-kohle* or pitch coal; next above come the fossil Calamites shown in the thick *Russ-kohle* seam. Above this comes the Annularia, and last of all the fern zone, traceable in the uppermost seams.

East of the Rhine is the large and important Westphalian coal-field of the Ruhr. Coal was got at Dortmund as early as 1302, but only within the last century has the field attained any great importance. In the 1,203 fathoms of strata there are no fewer than 117 seams, making in all 294 feet of coal. Nearly three-fourths of this number of seams are of workable size. They have been carefully mapped out with the aid of several guide-seams of special character and persistence, and the strata have been grouped into three parallel systems. Of late years systematic boring through the chalk strata which overlie the coal measures on the north have proved the extension of the field in that direction, and have doubled its estimated productivity.

Germany's premier coal-field, and one of the largest and most notable in Western Europe, is that of Saarbrucken, on the left bank of the Rhine. Most of it lies in Prussia, but part of it also extends to Rhenish Bavaria (Rhein-Pfalz). This great coal-belt is about 60 miles long and 30 miles wide. Its lower strata

are estimated to reach the amazing depth of 20,682 feet, or nearly four miles, where, however, as the temperature will reach about 467° F., it is, and will doubtless remain, beyond human reach. The Prussian mining officials, after careful surveys, reported that the total number of seams was 164, containing in all 338 feet of coal. The number considered workable was 77, with 240 feet of coal. A peculiarity of this field is that the lowest seams are bituminous or caking-coal, and that the higher their position in the series, the drier, denser, and more anthracitic they become.

The remote and imperfectly developed coal-fields of Silesia are of great potential importance. That of Lower Silesia extends into Bohemia on the south-west, while that of Upper Silesia passes on the one hand into Moravia and Austrian Silesia, and on the other by way of Beuthen towards Cracow. The measures at their maximum, from the saddle of Zaborze towards the outcrop, are said to be 10,000 feet deep, and to include a total thickness of 333 feet of coal. Both miners and geologists agree that this coal region round the headwaters of the Oder is one capable of great development, and that its supplies of coal will outlast those of the older western fields.

Across the Austrian frontier the true coal formation extends from Lower Silesia as far as the base of Riesengebirge, and that of Upper Silesia forms a zone of considerable importance. To the north-west of Prague, the coal-basins of Schlan, Rakonitz, and Radnitz, and farther west, that of Pilsen, have been fully developed. There are seams of brown coal or lignite worked not only in the flat country about Elnbogen, but also at Gran near Buda-Pesth, and in Styria and Carinthia. Nearly one-half of the total amount of coal raised in the Austrian Empire consists of lignite.

The opening-up of the coal resources of Russia is

of comparatively recent date. The abundance of wood fuel, the scattered population, and the absence of transport have all tended to retard the development of coal-mining. The researches of Sir Roderick Murchison proved the existence of a vast extension of the coal measures, which range along both flanks of the Ural mountains for hundreds of miles.

The Silesian coal-field extends across the frontier into Russian Poland. There are important fields in the governments of Tula and Kaluga, with an area of 13,000 square miles, and in the lower valley of the Donetz. The Donetz coal-field, lying between the Don and the Dnieper and north of the Sea of Azov, covers an area of 11,000 square miles. It contains numerous valuable seams and is at present the most productive coal-field in Russia. A feature which it shares with that of South Wales is that the beds of coal, from being highly bituminous in the west, pass by almost imperceptible gradations into anthracite in the east.

The Mediterranean countries, with one exception, are devoid of true coal, and are possessed only of rare and unimportant deposits of lignite. Spain is the single exception, and, amongst her other mineral treasures, can number large coal-fields with numerous seams near Oviedo in Asturias, and others at Belmez and Villa Nueva, near Cordova.

The North American continent is rich in the possession of extensive coal-fields, the Appalachian region of the United States being one of the largest and most important coal-basins in the world.

In the British colonies of New Brunswick and Nova Scotia the carboniferous strata are of exceptional depth. An interesting feature is that the fossil plants found in the coal measures are of the same species as those found among British and European coals. The Cumberland field is the largest coal-bearing tract, having

an area of 6,889 square miles. Although it contains seventy seams of coal, most of them are thin and unworkable, and it is more interesting from a scientific than a commercial point of view. The total thickness of the series has been calculated by Sir W. Logan to be 14,570 feet, with seventy-six seams of coal. There is a unique natural exposure of strata at South Joggins, on the shores of the Bay of Fundy, which brings to the surface no less than 4,515 feet of the coal measures. The beds rise along the base of the cliffs, clean and fresh, to a height of 150 feet; so that in travelling along the shore one has unfolded a novel geological panorama. Sir C. Lyell counted nineteen coal-seams and the remains of at least ten forests of Sigillaria.

The Pictou coal-field has an area of 350 square miles, and contains some unusually thick seams, one—the Pictou main coal—of 37 feet, and three others aggregating as much more. According to Sir J. Dawson an extension of these great beds of coal has been proved and the field is estimated to contain workable coal to the amount of 150 million tons.

The coal-fields of Richmond and Cape Breton underlie a combined area of 350 square miles, of which about 250 square miles is workable and productive. The coal measures are found to extend to a depth of 10,000 feet. There is another fine natural section north-west of Sydney Harbour, which shows a thickness of 1,860 feet of strata.

Turning to the great coal regions of the United States, even a cursory examination of their character and position drives one to the conclusion that, large as they are, they are simply the remnants of an immense coal area which once extended from the St. Lawrence to the mouth of the Mississippi, and from the Atlantic coast to the Rocky Mountains. The three greatest coal-zones in point of size are the Appalachian, which

covers an area of 63,475 square miles, the Illinois, with 51,700 square miles, and the Missouri, which extends nominally to 100,000 square miles.

In the central and western fields the strata lie regularly, and only slightly removed from the horizontal, but on proceeding eastwards and approaching the Alleghanies, the measures become crumpled and folded. Corresponding with this folding of the beds, the coals lose their bituminous properties, and, along the western flanks of the mountains, occur only as anthracite. There is a marked connection apparently between the crumpling of the coal-seams and the loss of their volatile constituents, which makes them anthracitic, for the farther from the axis of the disturbance the more bituminous the coals are found to be.

The great Appalachian coal-field is really a series of basins extending through Pennsylvania, Ohio, Maryland, Virginia, Kentucky, and Tennessee, a distance of 875 miles. In the southernmost or Pottsville anthracite basin there are in some parts twenty-five workable seams, in others not more than ten or twelve; while the thickness of coal varies from 70 to 200 feet. Some of the lower seams are from 10 to 40 feet thick, the great coal-bed at Lehigh Summit yielding over 30 feet of good coal.

The bituminous field of Western Pennsylvania, containing seven to ten workable seams in a depth of 2,100 feet, crops up again in North-west Virginia; but the fact that the strata decreases to a thickness of 700 feet in Missouri and Iowa proves its gradual attenuation westward. The upper series, outcropping north and north-west of Pittsburg, is based upon a remarkable seam named after the town. This seam, with a thickness of 8 feet at Pittsburg, increasing to 12 or 14 feet in the south-east and decreasing to 3 or 5 feet in other places, covers a superficial area of 14,000 square

miles. It is its great extent that makes this field so remarkable and productive rather than the thickness of the coal-seams, for the aggregate thickness at any point does not average more than 25 feet.

The Illinois coal area is an oval tract embracing two-thirds of Illinois and parts of Indiana and Western Kentucky. Within this large district local disturbances have caused undulations of the strata, and confined the basins to limits which have not been fully defined. In Western Kentucky the productive coal measures are estimated to be 3,429 feet thick, with seventeen seams and a total of 40 to 50 feet of coal. The best coal in this field is found in Indiana, and although it is not equal to the Pennsylvania fuel, it is cheap and plentiful.

In the other great coal-field, which covers the south-western part of Iowa—the best portions being along the Des Moines River—and extends into Missouri and Kansas, the beds of coal are neither thick nor numerous. Professor Swallow, reporting on the geology of Missouri, estimates the thickness of the coal measures at only 650 feet.

A large area of Central Michigan is occupied by a shallow basin of gently inclined or horizontal coal measures, but the seams are thin and of a poor quality.

Coal is also found in Texas; and in Colorado and New Mexico, the late Dr. Hayden, of the U.S. Government Survey, reported the existence of great quantities of coal associated with iron ore, especially in the districts now known as the Laramie coal-fields. The most important extends across the border between Colorado and New Mexico and occupies an area of 2,200 square miles.

The traveller who set himself the task of visiting the coal-mining districts of the world would find little to do on the Pacific Coast of America. It is a curious fact, as Mr. James Macfarlane * has placed on record,

* "Coal Regions of America," Ch. XX. p. 561.

that "no true carboniferous coal has ever been found in California, Oregon, or anywhere along the Pacific coast." The formations on the Pacific slope are all later than the true coal measures, and while in the light of recent discoveries in Alaska it is hardly correct to say that all fossil fuel "from Behring's Straits to those of Magellan" is lignite, still the majority of it certainly is of that variety. On Vancouver Island and on the opposite coast of North America there are extensive deposits of lignite, of which those at Nanaimo are the best. Mr. Isbister describes extensive beds of lignite in the valley of the Mackenzie, which have been traced by Sir J. Richardson to the ice-bound shores of the Arctic.

There are several large tracts seamed with coal in Northern India. The largest and most important field at present worked is that of Ranigunj, which lies on the rocky frontier of Western Bengal and is distant about 120 miles from Calcutta. The principal mines are in the centre of the field, and the numerous chimneys and waste-heaps make this the "black country" of India. Many of the seams are of good thickness, but the quality of the coal is inferior.

There are several coal basins in the valley of the River Damuda which were no doubt parts of one continuous area, but have been separated by denudation. The Godaveri valley contains numerous coal areas of some potential importance, of which the Wun field has by far the largest actual and available amount of coal. Five distinct coal-fields exist in the valley of the Brahmaputra, in the province of Assam. These should prove of commercial importance, as coal for the use of the steamers plying on the Brahmaputra has hitherto had to be carried 1,000 miles. In the valley of the Nerbudda, in Western India, coal is known to exist over a wide area, but—and this applies to many

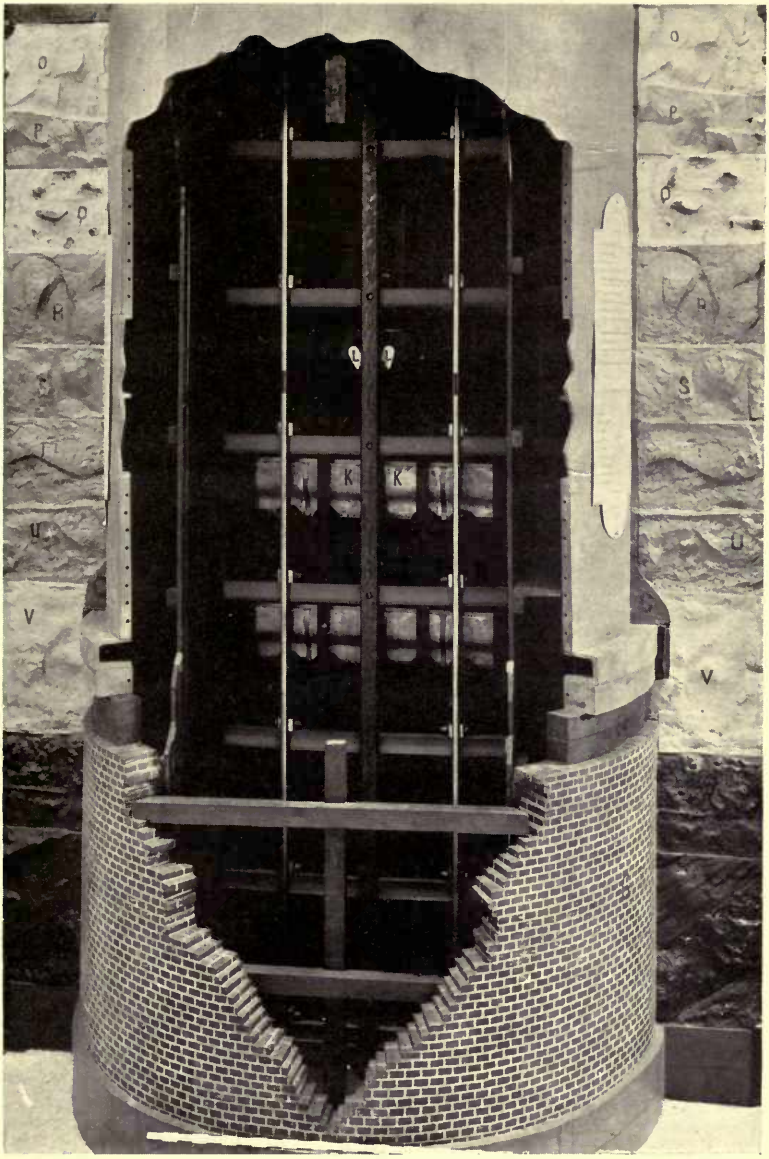
of the coal-bearing districts of India—in the absence of actual mining operations the exact extent of the coal resources is unknown. Taken altogether, however, they offer sufficient guarantee of India's future industrial development.

There are immense deposits of coal in China, which, when more fully developed, will probably place it in the front rank of coal-producing countries. In China proper the largest coal measures are found in Shansi, Hunan, Kweichow, and Szechuen, and many of the other provinces have also fields of more or less value. Numerous small mines have been worked by the natives in Hunan and Shansi, but the lack of transport and the objection to the introduction of foreign methods and capital has checked the development of the coal-fields. The largest field in China lies in the province of Shansi. The whole of the southern part of the province is one vast coal-field extending over an area of 30,000 square miles, and containing, according to Baron von Richthofen, enough coal to last the world at the present rate of consumption for several thousand years. The coal-seams, which are from 20 to 36 feet in thickness, are practically horizontal. Their limestone bed is raised some 2,000 feet above the surrounding plain, and the seams outcrop in all directions. Mining is carried on by driving adits into the face of the formation, and is thus rendered extremely simple. The coal-field is divided into two parts by the Hoshan mountains. It is a strange fact that on the east side of the range the coal is anthracitic, and on the west side bituminous. A concession to work coal and iron in this area was granted to the Peking Syndicate, a British concern, together with the right to build railways to connect the mines with water navigation. The syndicate constructed a railway in Shansi from Pingyang to Tsichowfu, the

centre of a vast coal-field, and connected with the Peking-Hankow main line. There are also important collieries at Kaiping, in the east of the province of Chihli, which are connected by rail with the seaport of Taku. The coal at Kaiping is soft and bituminous, with a large proportion of dust. Other coal-fields are being opened up, and everything points to the probability of a new era when the awakening of China reveals her wealth in that most valuable of industrial assets—coal.

In Japan coal-mines are worked in the districts of Kiusiu and Niphon. There are also important collieries in Hokkaido, most of which are operated by one company, which ships coal from the ports of Otaru and Muroran to Shanghai, Hong-Kong, Manila, and even Singapore, 2000 miles away.

Coal was found in New South Wales as long ago as 1797, and important seams are now worked at Newcastle and elsewhere in that colony, as well as at Ipswich in Queensland. Owing to the demand for fuel for the gold-mining plants on the Rand, the coal-seams of the Transvaal have attained an importance that they might otherwise never have reached. The coal resources of South America have not been sufficiently investigated to merit more than passing mention in our tour of the world's coal-fields.

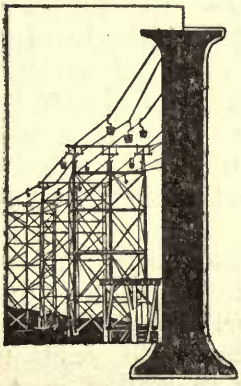


MODEL OF SHAFT TUBBING AND CAGE.

Do not
circulate

CHAPTER XVII

MODERN MINES AND MINERS

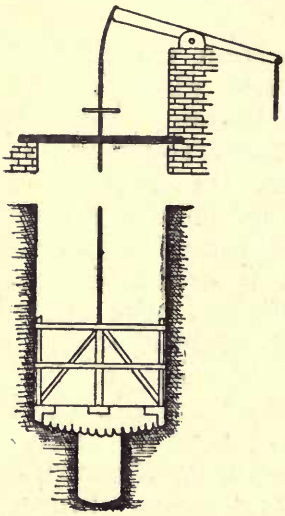


HAVE treated to some extent of the origin, history, and distribution of coal, and it now becomes necessary, in order to bring home to the reader's mind more vividly the story of the coal-mine, to endeavour to describe the practical working of a modern colliery. To do this with any degree of completeness would require a portly tome, so that only a brief sketch is possible. It will be best to begin before the sinking of the pit, at the point where the landowners—or the persons who, having satisfied themselves that coal exists under the surface, have leased the rights from the landowners—proceed to make arrangements to work the coal.

Having ascertained, first by surveys of the surface and of the strata, and secondly by boring, the number, inclination, and extent of the coal-seams and the nature of the ground to be penetrated, the mining engineer must first decide the position of the shafts—for in this country every colliery must have two outlets. The primary consideration is, of course, to secure the most economical winning and getting of the coal, and the efficient development of the projected mine. If, as sometimes happens, the coal outcrops on the

property, it can—though this is seldom if ever done in this country—be worked by open workings, or, if the country be hilly, by adits or drifts. These are, however, only temporary measures, and in most modern mines vertical shafts are sunk as soon as possible.

In fixing the position of the shafts the contour of the country has to be taken into account. While the best position would of course be in the centre of the property, it would be absurd to sink the shaft from the top of a hill if the coal is below the level of a neighbouring valley. The character of the strata has also to be considered. Loose ground, sands, and gravels are avoided if possible, and even more particularly, watery strata.



SHAFT-SINKING, KIND-CHAUDRON METHOD.

The shaft is excavated in soft earth by pick and shovel, the sides being timbered as the work proceeds. When the solid rock is reached the shaft is walled in to make it secure, and then sinking is resumed through the rock by means of holing and blasting. To prevent the influx of water during the sinking of the shaft many ingenious methods have been employed. Of these the best known and most widely used is that already referred to as "tubbing," which consists in lining the shaft with a watertight casing of wood or iron. Nowadays, iron is almost invariably used, in the form of segments forming cylinders or rings, which are bolted together to form a huge tube extending throughout the watery strata.

Perhaps the best-known method of penetrating

through water-bearing strata is that called the Kind-Chaudron process, which has been widely used in Belgium and Germany. The rationale of the process consists of the sinking of the shaft without pumping out any of the water, then damming off the water by means of tubbing, after which the water standing in the shaft is pumped out and sinking is resumed. The shaft is bored in two operations by means of a cutter or *trepan*, first of small diameter, and then of the full diameter of the shaft. The Kind-Chaudron method has not been generally adopted in England.

The pneumatic process, which is operated by means of compressed air, has also been employed for sinking through watery strata. The shaft is lined with a cylinder of wrought iron, within which a tubular chamber equipped with double doors, forming an "air-lock," is fitted by means of an air-tight telescopic joint. Air is then forced into the enclosed space until the pressure is sufficient to check the flow of water into the shaft. The pit-sinkers work in the pneumatic chamber just as they would do in a diving bell.

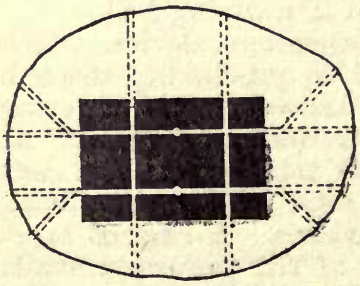
Still another extremely ingenious device, which has been successfully adapted to pit-sinking through quicksands and the like, is known as the freezing process. The method was introduced by Messrs. A. & H. T. Poetsch in 1883. By this system the soft or watery ground is rendered solid for the time being by being frozen by artificial means. A ring of bore-holes is sunk round the site of the projected shaft, and in them are placed a series of iron pipes. The freezing is effected by pumping brine, cooled to a temperature of about 5° F. (by the vaporization of liquefied ammonia), through the pipes. The watery strata is frozen solid, and the shaft may then be sunk in the ordinary way until the hard rock is reached, when walling or "tubbing" can be built upwards. The

freezing process must, however, be continued until the "tubbing" is completed.

The size and form of colliery shafts vary in different countries, and even in different parts of the same country. In the United States and Scotland rectangular timbered shafts are still common, but the modern tendency is to make them circular and varying from 9 to 20 feet in diameter.

Of the two shafts which are generally found in British collieries, one, for ventilation purposes, is called the "downcast" shaft and conveys the fresh air to the workings. The other is the "upcast," by which the foul air ascends from the workings to the surface. One of the first essentials in opening out a colliery in this country is to establish communication underground between the two shafts.

Before commencing to work the seams of coal, an area must be left unworked round the bottom of the shaft. This "shaft-pillar," as it is called, is allowed to remain intact so as to provide a sort of foundation to maintain the stability of the shaft and prevent any subsidence. The beginnings of the main roads or levels branching out from the "pit-eye" or bottom of the shaft towards the seams are excavated or built with plenty of width and height, as they are the focal and concentration points of the mine, providing ingress and egress for the miners, and sidings for the collection and distribution of the coal-tubs, trams, or wagons. After leaving the shaft sidings the "levels" are, if possible, cut with a slight decline towards the shaft



PLAN SHOWING SHAFT-PILLAR.

COAL-GETTING: AT THE BOTTOM OF THE SHAFT.

Digitized by Google

in order to facilitate drainage and the haulage of loaded wagons. The main roadways are securely timbered, or arched with brick or stone, more especially if the roof is of a loose or crumbly nature.

We will suppose then that the shafts have been sunk to a seam or seams of coal, that the colliery is equipped for winding coal to the surface, and that the preliminary work of forming the shaft-pillar, sidings and main roads has been carried out; then the working of the coal is commenced. The "lay-out" or method of working varies with the nature, thickness, and inclination of the seams, and with local conditions and customs. The numerous methods in vogue may be considered as modifications of one or other of the two distinctive modes known as "pillar-work" and "long-wall work." The first named, which is also called bord and pillar, bord and wall, post and stall, pillar and stall, and (in Scotland) stoop and room, has been extensively adopted in the North of England. It comprises two operations, one known as the "whole working" and the other as the "broken working." The former is carried out first, and consists in driving one set of excavations, called "bords," through the solid coal, and another set at right angles to these, called walls, headings, or headways. The bords, from 3 to 7 yards wide, are driven across the seam and produce the main supply of coal. The headways are narrow, and are intended chiefly for air passages. The double excavations leave chequer-like rows of rectangular blocks or pillars of coal to support the roof. In the latest development of pillar-working, the bords are from 4 to 6 yards in width, and the pillars average 30 yards long and 22 yards wide. Then as the miners gradually work their way backwards towards the pit-eye, these huge pillars are removed piecemeal, the roof being supported by pit props during

the process and then allowed to collapse, forming what is known as the "goaf," "gob," or waste.

By the Lancashire method of pillar-working the coal area is laid or mapped out by two pairs of parallel drifts. These are connected, other levels are driven forward to the boundary, and the coal and pillars are then cut back. By this plan the whole of the coal is worked backwards from the confines of the pit towards the shaft, the main roads running through the solid coal. In this way a greater amount of support is given to the roof, and the pillars are less crushed than by the other variants on the pillar-and-stall system.

The other distinctive mode of working a coal-seam is that known as long-wall or long-work, the essential feature of which is the removal of all coal in a certain area at a single operation, that is, without subdividing it into pillars. The roof is temporarily supported by wooden props or pack walls while the miners are working along the face of the coal. By this means the whole of the seam, with the exception of the pillars left to protect the shafts, can be removed. The roads for drawing the coal from the working faces to the shaft are kept open, when the unsupported roof is allowed to collapse all round, by means of pack walls built in the midst of the goaf or waste.

As to the comparative merits of the two principal methods even experts are divided. It is generally conceded, however, that long-wall work is best adapted to thin seams and those having a good roof—that is, one which, when supports are removed, collapses gradually. Pillar-working furnishes a smaller proportion of round coal as compared with "slack" or small coal. On the other hand, ventilation is more difficult. The great increase in the dimensions of the pillars in modern collieries, however, creates a

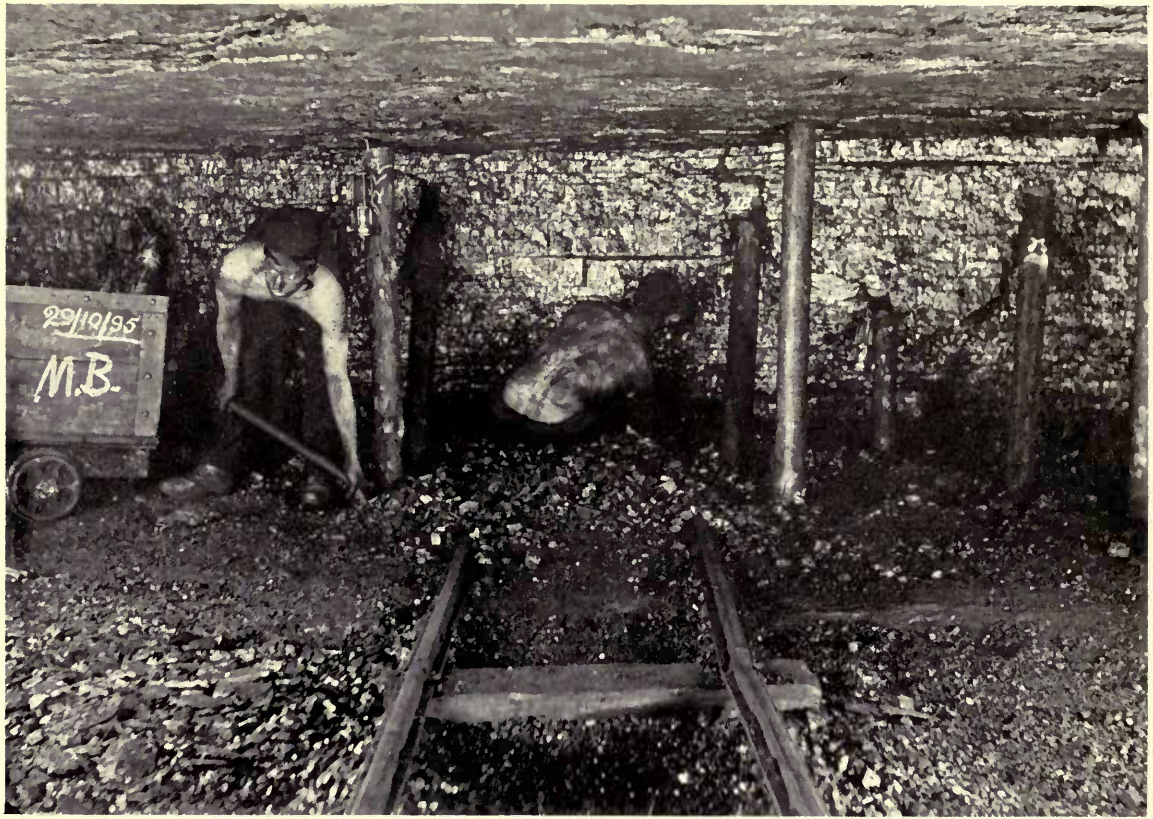
greater similarity between the two methods than hitherto. When the whole of the coal in one section is removed at one operation there is said to be less probability of surface damage through subsidence. The lowering of the ruined front of Newstead Abbey for several feet without injury is cited as a case in point.

The working of coal-seams of exceptional thickness offers peculiar difficulties, one of which is the problem of supporting the roof. The most familiar example is afforded by the thick coal of South Staffordshire, which, consisting of several closely packed seams, forms practically a great single bed of from 20 to 30 feet in thickness. In the usual method of working, a main road is driven in the " benches " coal or lower part of the seam, while a smaller air heading or passage for ventilation is cut in one of the upper beds, called the " slipper " coal. From the main or gate road a heading locally termed a " bolt-hole " is opened out and enlarged into a huge rectangular chamber known as a " side of work," large and small pillars being left standing at intervals.

The coal is excavated from below to the top of the slipper coal, after which the upper portion is either broken down by wedging or falls of itself. The working of these upper sections is extremely dangerous, owing to the height of the excavation, and fatalities from falls of roof are more common in the South Staffordshire mines than in any other British coal-field. About one-half of the coal in a given section of the seam is obtained in the first working. The roof is then allowed to settle down, and when the " gob " or debris is sufficiently consolidated, fresh roads are driven through it to recover the coal in the pillars left after the first working. The South Staffordshire method has been latterly to some extent superseded by a modified form of long-wall working in thick seams.

In the operation of thick seams inclined at a steep angle, such as those in the south of France and in the lignite mines of Styria and Bohemia, the system of working in horizontal slices about 12 to 15 feet thick is now very generally adopted, as also the practice of filling up the excavation with debris. In fact this filling up with waste is being extended to long-wall working of thin seams in France and Germany, and is compulsory in Westphalia wherever workings extend under buildings. In some American anthracite collieries the waste is washed into the exhausted workings by water, which is then pumped out. This method was first introduced in Silesia, and has spread rapidly to other coal-fields.

The actual excavation or cutting of the coal is still chiefly performed by manual labour. The tool used is a sharp-pointed, double-ended pick, which is also called a pike, mandril, or slitter. The man behind the pick is the collier proper, who is called a hewer or pikeman. In driving levels it is necessary to cut grooves parallel to the walls of the seam, but the most important operation is that known as "holing" or "kirving." This consists of cutting a slit under the coal to a depth of perhaps 3 feet, so as to leave the upper portion overhanging and unsupported, when it either falls down of its own weight or is dislodged by wedging or blasting. This work of holing in coal is performed by the miner while lying on his side or in some other constrained position necessitated by the exigencies of his task, is carried on in darkness only made visible by the dim light of his lamp, and is in fact one of the most arduous forms of human labour. In under-cutting a coal-seam by hand, the deeper the holing the wider the opening has to be made in order to secure room for the miner's pick. This causes some waste in "slack" or small coal, as



COAL-GETTING : COLLIERS " HOLING."

Property of
Archives

compared with more modern methods of coal-cutting by machinery.

The substitution of machinery for hand-labour in coal-cutting is a proposition that has long attracted inventors. Michael Menzies in 1761 proposed to work a heavy pick underground by power to be transmitted from an engine at the surface. This idea was improved upon in modern times by the pick machine of William Firth, of Sheffield, which was worked by an engine mounted on a railway truck, and did the work of twelve men. These mechanical picks have however been generally superseded by rotating cutters attached to an endless chain, revolving discs or wheels, or other devices which are more continuous in action. The principal advantage claimed for mechanical coal-cutters over hand labour is the cutting of a narrower groove and the smaller proportion of waste. It was not, however, until the adoption of the valuable medium of compressed air as a motive power that coal-cutting machines came into anything like general use.

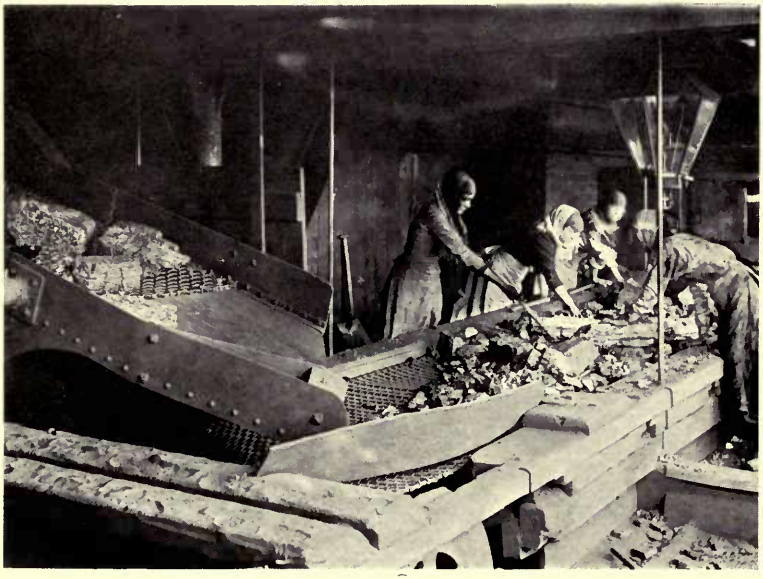
The principal types of coal-cutting machines may be divided into those suitable for bord-and-stall work, viz. the pick or percussive and chain cutting devices, and those used in long-wall working, which are chiefly of the disc, bar, or chain varieties. A simple form of the saw or spur-wheel coal-cutter is that of Messrs. Winstanley & Barker, which is driven by a pair of oscillating engines placed on a frame running on rails. This type has latterly been greatly improved, and is one of the most widely used machines of this class in British mines. Another class of coal-cutter originated in America about the year 1887. They are really large rock-drills, without the rotating gear for the cutting tool, and are mounted upon a pair of wheels placed so as to allow the tool to work on a forward slope. These holing machines, of which the best-

known makes are the Ingersoll-Sergeant, Harrison, and Sullivan, are more widely employed in America than in this country. When in operation the miner controls the direction of the blow of the percussive pick or drill by means of the two handles at the back of the machine, which is capable of delivering from 150 to 250 blows per minute.

In this country the majority of the coal-cutting machines are nowadays employed on long-wall faces, and are of the disc type. They consist in the main of a rectangular iron frame mounted on wheels and carrying the driving gear. On one side of the frame is bolted a bracket which supports the disc or cutting wheel, armed with teeth somewhat after the manner of a circular saw. The disc or cutter revolves horizontally and undercuts the coal close to the floor of the seam. Rails are laid parallel to the coal face, along which the machine slowly travels as the disc performs its function of holing or grooving.

The "putting" or conveyance of the coal excavated from the working face to the "pit-eye" was formerly, and is still in small mines, performed by manual labour. Nowadays for the most part it is effected by horse or mechanical traction in "trams" or "tubs"—as the pit-wagons are called—running upon rails. In a large colliery where the shafts are located near the centre of the workings, and these extend not only on all sides but on different levels, there may be three different kinds of roads provided for the haulage of the mineral. First there are the ordinary levels, suitable for horse traction; secondly there are sloping passages known as "jinny-roads," "jig-brows," or "up-brows"; and thirdly there are the "dip-" or "down-brows." The up-brows, if of sufficient gradient, are frequently utilized as self-acting inclines, that is to say, the loaded wagons in descending are

Cleaning Fuel.



Screening and Sorting Fuel.

UC STATE
CALIFORNIA

made, by means of a rope, pulley, and brake, to pull the train of empty wagons up the slope. The dip- or down-brow, on the other hand, requires engine-power.

The two chief methods by which power is applied to underground traction are the tail-rope system, and that of the endless chain or rope, which latter may travel either on the ground or over the wagons. In the tail-rope system, which is largely used in Durham and Northumberland, a single line of rails is used, and the wagons are run in opposite directions by reversing the hauling engine. For the endless-chain system, which was formerly much used in the Wigan district, but is now, however, practically obsolete, a double line of rails was requisite, one for laden tubs and the other for empties. The chain was propelled continuously round the circuit, like the cables on some tramway systems, and when the wagons were hitched on to it, it carried them along at the rate of 3 or 4 miles an hour to or from the pit-eye.

The drawing or winding of the coal from the bottom of the shaft to the surface is one of the most important operations in coal-mining, and one in which mechanical appliances have been brought to a high degree of perfection. The surface fixtures and plant of a colliery are so arranged that the maximum output can be dealt with rapidly and efficiently. The central feature is the head-gear, the familiar upright frame of wood or iron, stayed by sloping beams, rising to a height of from 50 to 100 feet above the ground level, and supporting two huge pulleys. Over these pulleys, which are sometimes 20 feet in diameter, run the steel ropes by means of which the winding engine raises and lowers the men, coal, and empty wagons. The full tubs are run into the cage—a platform with a vertical iron framework and consisting of two or even four stages or decks.

When the coal-tubs are wound to the top of the shaft, they are seldom removed from the cage at the actual surface level. Usually a stage or platform of wood or iron, called the pitbank or heapstead, is erected at a height of 20 or 30 feet above the ground, and there the cages are stopped and the full tubs are changed for empties. The purpose of having a staging of this height is so that the coal may be screened, washed, or classified without the necessity of raising it a second time. The laden tubs pass over a weigh-bridge and are weighed and "tallied" by two weighers specially appointed for the purpose by the coal-owner and the colliers respectively. They are then run into "tipplers," which overturn and so empty them on to screens, mechanical conveyors, carts, or railway wagons. The empty tubs are then returned to the cage ready to be lowered once again.

In British collieries the winding of coal is, for the most part, confined to the day-shift of eight hours, and the output may be anything from 100 to 150 tons per hour. At Cadeby Main colliery, near Doncaster, in 1906, 3,360 tons of coal were drawn in fourteen hours from one pit, 763 yards deep. In some of the deeper German collieries, in which the initial expenditure has been heavy, complete duplicate winding equipments have been fixed, and with such a dual plant from 3,500 to 4,500 tons of coal have been raised in the double shift of sixteen hours.

One of the most vital necessities to the health, safety, and efficiency of the colliers, and therefore to the proper working of the colliery, is a thorough system of ventilation. This involves not only a plentiful supply of fresh air to the men in the pit, but the removal of the inflammable gases that are in many cases given off by the coal. A current of air, large in volume and steady and continuous in motion, is sent through

the workings. This circulation is effected either by rarefaction of the air, due to a furnace placed at the bottom of the upcast shaft, or by fans or other machinery. The first named is the older system, and has been very largely used, but it is obviously unsuitable for fiery mines, and is being replaced by mechanical ventilation with huge fans. The actual conveyance or coursing of the air from the intake to the working faces where the miners are employed, is effected by dividing the current at different points in its course and directing it by means of brattice cloth screens to where it is wanted.

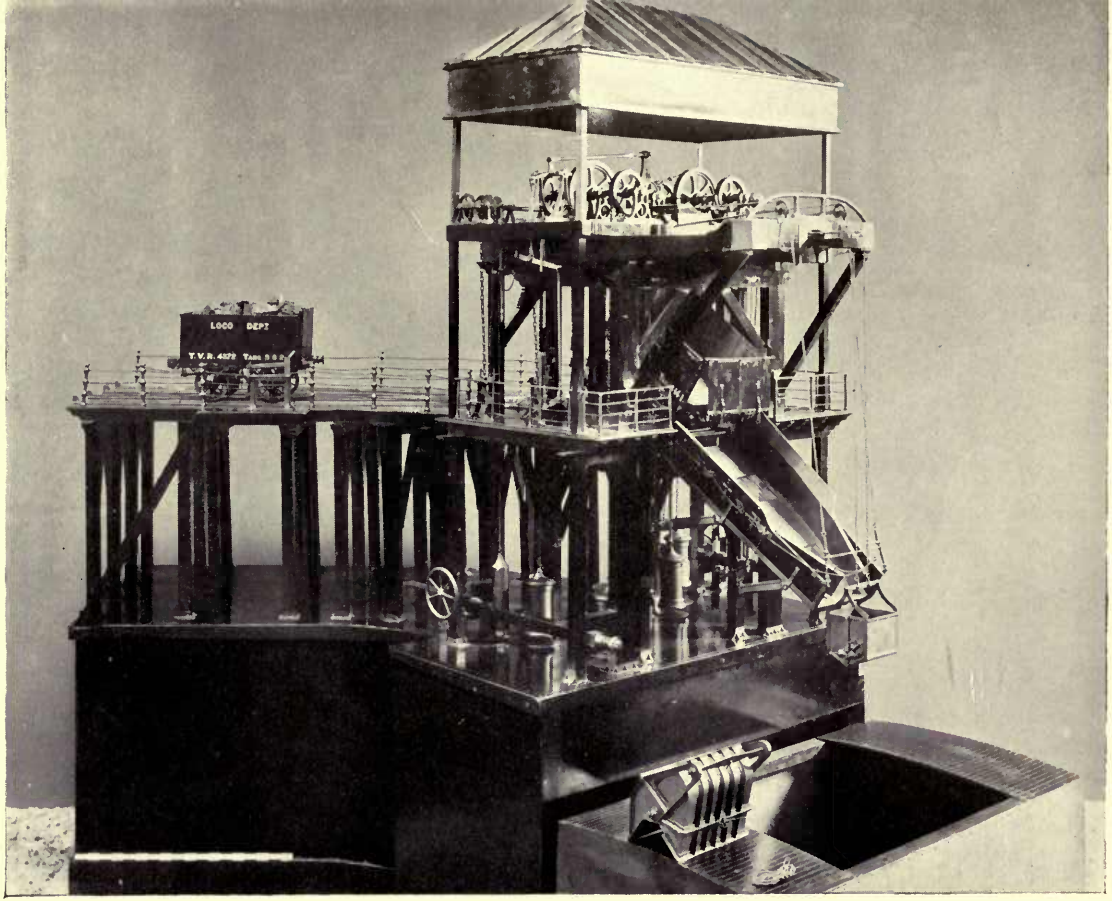
The lighting of the underground workings in collieries is closely connected with the ventilation. Both are necessary for the efficiency of the miner. In some of the small pits in the Midlands and particularly in South Staffordshire, the seams are so free from gas that naked lights, generally candles, are used with impunity. Oil lamps are utilized in Scottish mines, and almost universally in those of Belgium and other European countries. The problem of lighting in fiery mines has, however, long been a much more serious and difficult matter. Light is, of course, necessary to enable the miners to work, and yet the introduction of a naked or unprotected flame into a gassy mine may cause a terrible explosion. Sir Humphry Davy, as we have seen, was the pioneer in the evolution of a real safety lamp for use in mines liable to the presence of gas.

The Clanny lamp, a successor of the Davy, was the first safety lamp to include glass in its construction. It gave a better light than either the Davy or the Stephenson—a later lamp also called the "Geordie," which was largely used in the northern collieries. None of these lamps are now used in their original form, as they are unsafe in the high velocities of air

currents in modern mines. They may, however, be used in a modified form by being enclosed in cases and shields or bonnets of tin which prevent the air current from impinging directly on the flame.

Of modern safety lamps the Marsaut type is considered by experts to be the best and most reliable. The Mueseler, which resembles the Clanny with the addition of a gauze diaphragm and a conical metal funnel, is now only considered safe if provided with a tin shield or bonnet. The Marsaut is an improved Clanny lamp. It has two and sometimes three gauze cylinders, one within the other, and they are covered with a tin bonnet. The products of combustion, before escaping, pass through the double or treble gauze. This Marsaut lamp is considered very safe and is largely used. Both the Marsaut and the Mueseler give a much superior light to the Davy, Clanny, or Stephenson. Whereas the Clanny had an illuminating power of only one-fifth of a candle-power, and the Davy and Stephenson even less, the two more modern types give a light of nearly half a candle-power.

The nature of the gases given off by coal-seams when they are opened up in the working of a colliery have been investigated by several eminent chemists, notably Messrs. Lyon Playfair and Ernst von Meyer. Broadly speaking, the "firedamp" of the miners consists to a large extent of marsh gas or light carburetted hydrogen. This gas, issuing in sudden outbursts or "blowers" from the coal, is the most dangerous enemy the collier has to contend with. Steam coal, particularly in South Wales, frequently gives off enormous quantities of gas from the working faces in the deep pits, many of which have been the scenes of disastrous explosions. It is a remarkable fact that firedamp is only explosive when mixed with from four to twelve times its volume of air. When the propor-



MODEL OF COAL-TIP, WITH ANTI-BREAKAGE BOX (1896).

UNIVERSITY OF CALIFORNIA

tion is above or below these limits it simply burns with a pale blue flame.

Among the first to direct attention to the additional danger of explosions arising from or being intensified by the presence of coal-dust in the air of dry mines was Professor W. Galloway, and the danger is now generally recognized. The risk is minimized by the systematic sprinkling of the main roads and workings of the colliery with water or chemical solutions.

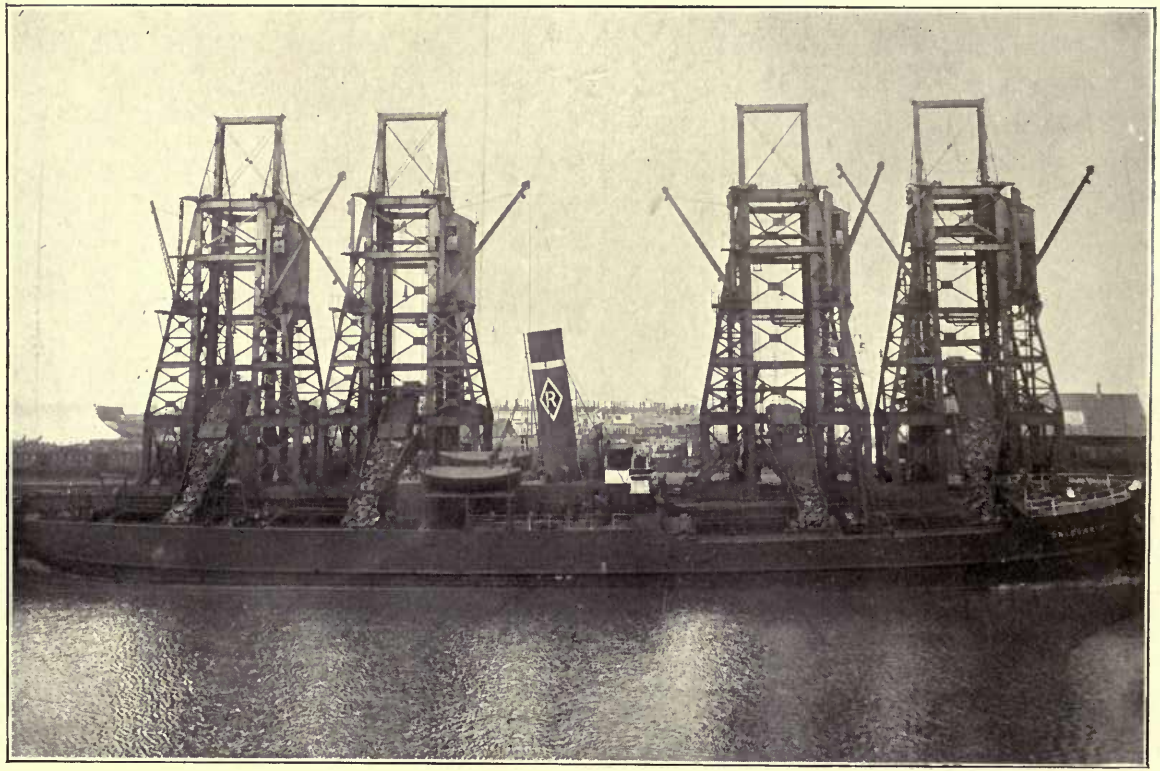
But despite all the precautions that have been and are taken, and notwithstanding the introduction of the most scientific and improved methods and appliances for his safety, the daily task of the collier, toiling it may be thousands of feet below the surface, remains a frightfully arduous and dangerous one. The toll of the pit has been a terrible one. Let me cite a few typical examples.

It was in 1862 that the catastrophe happened at the Hartley Colliery, Northumberland, which showed the risk of having only a single shaft in a mine, and called forth legislation which made two shafts compulsory. The great beam of the engine snapped, and a huge piece weighing 40 tons fell into the shaft, completely blocking the sole means of egress for the 200 men and boys in the pit. The herculean task of cutting a way through the obstruction was at once begun, and continued day and night. For some days it was hoped to save the entombed men, but the sounds they made in working for their own delivery grew fainter and at length ceased. It was not till six days later that a hole was cut through the obstruction big enough to allow a man to pass. Then it was found that all below had perished. Bodies were found in all directions and positions: many lay placidly as if they had swooned away or died whilst asleep. One poor fellow had roughly scratched on a tin flask the moving words, "Mercy, O God!"

Four years later a terrible explosion occurred at the Oaks Colliery, near Barnsley. Some 350 men were at work in the pit, and the worst was feared. Weeping mothers, wives, and children crowded round the pit-head. The men on the surface were moved to swift and heroic action. Scarcely an hour had elapsed before three brave fellows descended the smoking inferno. Their report was of the gloomiest. Some of the bodies were charred and disfigured. Other poor fellows were sitting up with their heads resting on their arms in the long sleep that knows no waking. Nothing further could be done that night, and the pit was left in charge of a young mining engineer, named Parkin Jeffcock, who had already distinguished himself at the flooding of the Clay Cross colliery a few years previously. Next morning, despite his ghastly night's vigil, Jeffcock joined a band of gallant explorers. Sad to relate, there were two further explosions in quick succession, and of Jeffcock and his fellow-heroes only one lived to tell the tale. The death-roll in this triple tragedy numbered over 380.

A mere recapitulation of the numerous disasters which have cost the lives of thousands of miners would make but sombre reading, illumined though it would be by the acts of heroism which stand out the more nobly against the background of gloom. I cannot linger over the horrors of Abercarn, where, in 1878, 268 perished, or on the horrible holocaust of Courrières in 1906, the Maypole Pit disaster at Wigan, or the terrible disaster at Whitehaven in 1908.

In a more recent catastrophe—that at Pretoria Pit, near Bolton, on December 21, 1910, when in one single blast of doom 343 men and boys were swept into eternity—the tale of disaster was, as ever, relieved by numerous acts of bravery and devotion. One sturdy, veteran miner lost his life while seeking to rescue his



Taff Vale Railway Co.

FOUR COAL-TIPS AT WORK, PENARTH DOCK.

Digitized by Google

two sons. Of the sights below after the explosion one member of a rescue party said : " It is something awful what I have seen. I came across a group of ten men. Some of them had been knocked about, but most of them had just fallen asleep. One poor fellow had his breakfast-can between his legs, and another had his handkerchief close to his face. Some of them were bonny chaps. I can tell you it was awful, but it is a good job they died in their sleep." A sweet-faced, motherly woman was bereft of her husband and four sons. Three she saw buried, and next day was waiting at the pit-head for tidings of the lost ones not yet recovered. And yet she bore her great sorrow with a sublime fortitude. But perhaps enough has been said to give some faint idea of the terrible toll which the pit exacts from the ranks of the sturdy fellows who risk death in their daily task.

There have been innumerable instances of heroism among the miners and others who have formed rescue parties with the object of succouring possible survivors after these colliery disasters. Many a brave fellow has been overcome by the deadly afterdamp which lurks in the pit after an explosion. Numerous primitive devices were tried to baffle this deadly enemy, but it was not until the middle of the nineteenth century that a practical respiratory apparatus was devised, consisting of receptacles containing compressed air. Then Professor Theodor Schwann suggested the use of compressed oxygen, the vitiated air to pass through a regenerator which purified it and added oxygen.

The best-known apparatus of this type is that perfected by Herr G. A. Meyer at the Shamrock colliery in Westphalia. There the first rescue station was formed, where a body of men are kept in regular training in mine rescue work aided by the apparatus. It was this corps that rendered such magnificent service in

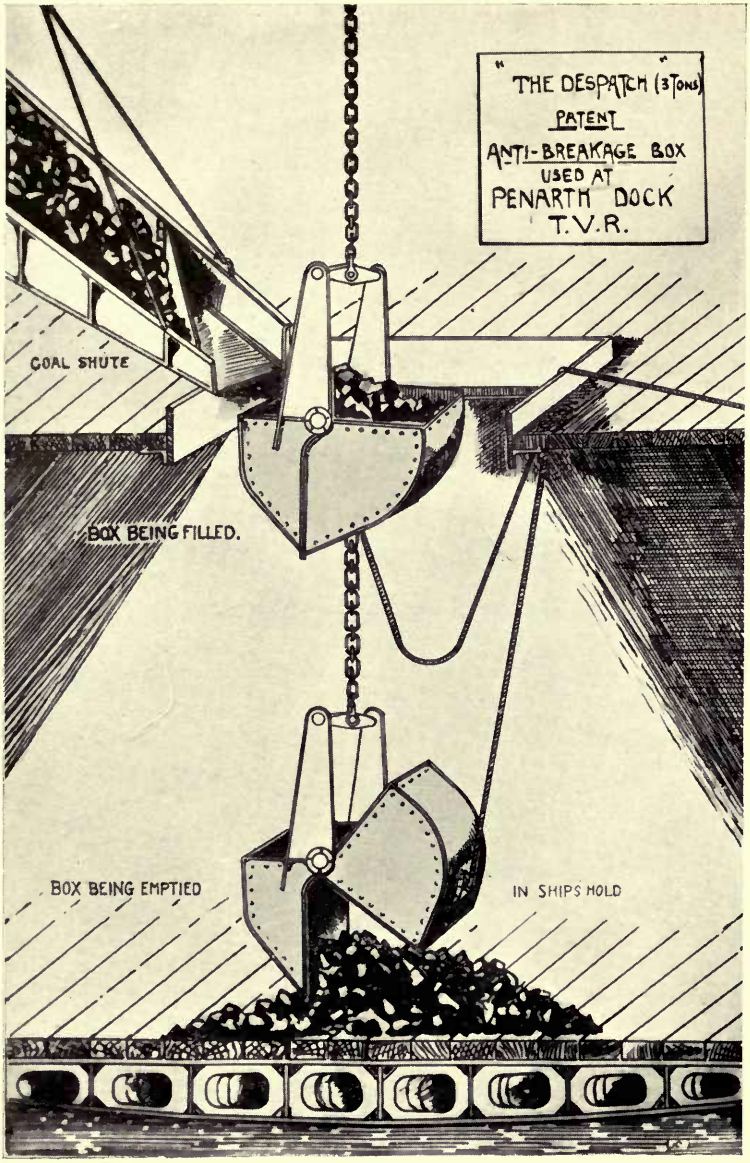
the exploring and rescue operations after the terrible explosion at Courrières in March 1906, when 1,100 miners were killed in the most disastrous mining accident ever recorded. Similar rescue stations have since been established at Howe Bridge in Lancashire and other mining centres in Great Britain; and by means of the Fleuss and other apparatus valuable exploratory work was done after the Whitehaven and Pretoria Pit disasters.

Acting on the principle that prevention is better than cure, repeated investigations have been made into the causes of explosions in collieries. Various causes have been assigned—the illicit opening of a safety lamp or striking of a match, or a flash in the electrical apparatus so largely used nowadays—any of these may cause an explosion the violence of which might be increased tremendously by the presence of coal-dust in the air. But although the most appalling death-rolls are generally due to explosions which only happen occasionally on a large scale, a much higher and increasing proportion of the fatalities to miners is due to falls of roofs and sides of seams. It is a melancholy fact that, on an average, "summer and winter four men and boys are brought up dead every day" * from British pits.

Yet, despite this lamentable toll and the fact that every time the miner descends the pit he is taking his life in his hands, coal must be got; and realizing this, he turns philosopher. The collier is a cheery, sturdy fellow, generally short of stature, strong of arm, and blunt of speech. In the northern coal-fields the trade is almost hereditary, the men of some families having been miners for generations. The Lancashire and South Wales collieries have attracted a good

* Mr. C. F. G. Masterman, House of Commons, December 15, 1911.

UNIV. OF CALIFORNIA



Taff Vale Railway Co.

PLAN OF ANTI-BREAKAGE BOX FOR COALING.

CLOSED
STACKS

many workers of Irish descent, while in some of the Lanarkshire pits, particularly about Bellshill, there are hundreds of Polish miners. In the American mines are to be found men of nearly every European nationality.

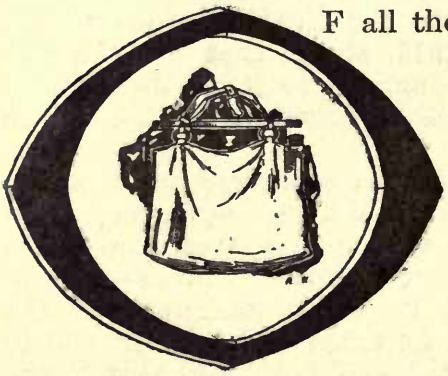
A brief résumé of the story of the coal-mines such as this can be most fittingly brought to a close by an attempt to glimpse the future from the data supplied by experts who have considered this vital question of the coal supply. So far as the British coal-fields are concerned the Royal Commission on Coal Supplies reported in 1906 that the reserves in proved fields reached the huge total of 100,000 million tons. Sir William Ramsay, in his address to the British Association at Portsmouth in August 1911, stated that "if the rate of working continues to increase as it has been doing since 1870, these fields will be completely exhausted in 175 years."

Turning to the comparative resources and supplies of the various European coal-fields, according to a calculation made by Mr. P. Frech in 1900, and based on the rate of production at that time, the coal-fields of Central France, Central Bohemia, Saxony, and the North of England would be exhausted in from 100 to 200 years; the other British coal-fields and that of the North of France in 250 years; those of Saarbrucken, Belgium, Aachen, and Westphalia in 600 to 800 years; but those of Upper Silesia not for more than a thousand years. Although some of these periods seem comfortingly remote, yet the very possibility of exhaustion is disturbing, and should move the powers that be to take steps to conserve the product of what the Germans appropriately call the "Robber Industry"—for coal once taken can never be replaced.

IRON

CHAPTER XVIII

THE STORY OF IRON



OF all the metals known to man, iron is by far the most useful, the most abundant, the strongest, and the most indispensable. It is found almost everywhere in some form or other, and in this, the age of steel, its uses are even more varied than the forms in which it occurs, and the sources from which it is derived. The presence of iron may be detected in the most unexpected places. Not only does it occur in combination with other substances in the form of ores, and to a less extent in the native or metallic form of meteorites, but it is to be found entering into the composition of the most diverse substances, more particularly such as are red in colouring. It is present in red clays and sands and in most soils, and scientists tell us that the ruddy colouring of the ripening apple is due to the presence of iron. This most versatile and protean of metals, as is well

known, enters into the composition of the blood, and so, the cynic will suggest, plays its part even in the rosy blush mantling on the maiden's cheek.

Although iron is one of the strongest of metals it is also one of the most perishable. It is, as we shall see, liable to be attacked by the oxygen in air or water, with which it combines to form the familiar red oxide or rust. This rust soon attacks all iron if it is unprotected from the air, and is as well-known an aspect of iron as the grey colour of the metal itself. It is in fact one of the most unfailing proofs of the presence of iron in nature, and largely accounts for the red colouring already mentioned. But although the ores of iron are fairly plentiful in those parts of the surface of the earth to which we have access, the metal is almost certainly much more plentiful in those portions of the interior which man can never hope to reach. It has been calculated by scientists that at least one-fifth of the whole mass of this earth of ours consists of this ubiquitous metal.

Iron is in many respects unique. Its susceptibility to the mysterious power of magnetism and its qualities of hardening with heating and sudden cooling, place it in a class apart among the metals. It varies very much, however, in quality and properties, owing partly to the mode of preparation and partly to the admixture of other elements, for, unlike most metals, it is seldom produced or used in an absolutely pure state. But the most striking attribute of iron is its adaptability and suitability for the use of man. Primitive man may have done without iron, but its discovery and use was the beginning of a civilization which is largely based on iron. With iron weapons, tools, and implements man has fought and slain, made and wrought, and moulded history and nature to his will.

Iron, whether in its manufactured or native state,

is acted upon by air and moisture, the oxygen of the atmosphere combining with the metal to form oxide of iron, commonly called "rust." This no doubt explains the fact that so few relics of the iron articles and implements of antiquity have been preserved. Nevertheless we have abundant proofs that the knowledge of iron and its uses was fairly widespread at a very remote period.

The Scriptures make it clear that the use of iron was well known to the Hebrews. Tubal Cain, the sixth in descent from Adam, was the first iron-worker on record, for do we not read in Genesis that he was "an instructor of every artificer in brass and iron"? Nor was steel unknown then, as witness Job when he exclaimed, "He shall flee from the iron weapon, and the bow of steel shall strike him through." There are numerous other Scriptural references to the use of iron.

Excavations beneath the great pyramid of Gizeh in Egypt, in 1837, brought to light a small piece of iron used in the structure of that wonderful monument, and therefore in all probability dating back to about 4,000 years before the Christian era. The preservation of this, the oldest piece of iron known, may be attributed to the dryness of the climate. An iron tool has been found in the pyramid of Kephron, dating back approximately to 3500 B.C., as also some pieces of iron in the Black Pyramid of Abusir (*circa* 3000 B.C.).

The stages in the evolution of even the crudest methods of the smelting of iron is largely a matter of surmise. First the open and wasteful wood fire, with only the breath of the prehistoric iron-worker by way of forced draught. Then the excavating of a primitive furnace in the earth or rock of the hillside, where the winds of heaven made the embers glow ever and anon. Or again the ingenious artificer found, perchance, that

he could produce an intermittent blast, and save his own breath, by squeezing a goat-skin, or rather inflating and deflating it.

This, the germ idea of the bellows, was developed in Egypt at an early date. By means of hieroglyphics and wall drawings which must be some thirty-five centuries old, we are able to glean a good idea of the methods in vogue about the time of Thothmes III. for producing the forced draught essential to iron-smelting. The most ingenious contrivance consisted of a pair of goat-skin bellows. The operator had two goat-skins, one under each foot, and both connected with a single tube conveying the air blast to the fire. When a goat-skin was full the man pressed it with one foot and so expelled the air into the fire. At the same time he pulled a string which raised the second goat-skin and allowed air to enter through a hole in the upper part. Over this hole when the skin was full he deftly placed his bare heel, and his weight caused a current from the second goat-skin. In the meantime the first bag was being filled in similar fashion, and thus a constant blast was maintained from each of the pair of primitive bellows alternately.

The use of iron was also known to other ancient peoples. It is said that the natives of Crete first learned that iron could be smelted from the ores of the island through a forest fire. Iron is known to have been smelted and worked at a very early date in India. Traces of ancient furnaces have been found in the peninsula of Sinai. There is evidence too that the metal was known and used by the Assyrians, Babylonians, and Chaldæans. The Assyrians in particular are known to have employed iron tools, such as picks, hammers, knives, and saws. Mr. A. H. Layard, the distinguished Orientalist, discovered a saw in the ruins of Nimroud which he ascribed to the period about

880 B.C., and which is still preserved in the British Museum. It is in a remarkably good state of preservation, and bears a striking resemblance to the carpenter's saw of to-day. The use of iron for hammer-heads in ancient Nineveh goes to prove that the metal was cheap and plentiful, while the finding of remains of chain armour and iron helmets shows the high degree of skill which the Assyrian artificers had attained.

Though the use of iron in ancient Greece was by no means common, the Greeks were not only familiar with its manufacture and uses, but were early versed in the delicate art of hardening and tempering steel. The use of bellows was also known, for Homer represents Hephæstus as throwing materials, from which the shield of Achilles was to be forged, into a furnace, urged by twenty pairs of bellows. The Greeks obtained most of their supplies of iron ore from the Chalybes, who inhabited the south coast of the Black Sea. In the records of the reign of Alexander we find mention of four different kinds of steel, each adapted for certain purposes. Iron was, however, still produced in such small quantities, and at such cost in labour and fuel, that when the Macedonian conqueror invaded India it was considered valuable enough to be taken away as part of the spoils of the victorious army. The great difficulty in reducing and working it by the crude and primitive methods then in vogue caused the supply to be so restricted as hardly to keep pace with the demand, and the metal was accordingly highly prized.

In Rome, carpenters, masons, and shipwrights were using iron tools as early as the third century B.C., and Pliny wrote that "iron is to be found almost everywhere." The Roman supplies of iron ore were derived from Elba, and later from Spain. The Iberians

were skilled smelters of and workers in iron, in which their country was very rich. The Carthaginians, after their conquest of the peninsula, made good use of the skill of the Iberian artificers, and it was due to the superiority of the Spanish swords used by Hannibal's army in the battle of Cannæ (A.D. 216) that the Roman legions were outclassed. Even before this time, however, the Romans knew several different methods of hardening steel, of which the oil bath was the favourite for tempering tools.

Cæsar found when he invaded Britain that the natives had a rudimentary knowledge of the smelting of iron and the fashioning of rude weapons and implements of that metal. Iron scythes were attached to the axles of their war-chariots, and iron tools were almost certainly used in the construction of those vehicles.

In Roman times a very elementary method of smelting iron was in general use in Britain and Belgium. A conical hole was dug in the ground, generally in an exposed position such as on a hillside. A horizontal cutting allowed the wind to play on the bottom of the furnace. This crude form of blast furnace could only be utilized when the wind was in a certain direction, and at other times it had to lie idle. The development into furnaces, resembling what were latterly called "air-bloomeries," was a gradual process. At first these were simple conical furnaces, with a small opening below for the admission of air, and a larger one above for the escape of the smoke and fumes. These were also built in exposed situations in order that the wind might assist combustion. The fire being kindled, successive layers of charcoal and ore were placed in the furnace, and the heat was regulated by the opening or closing of the apertures below. By this process the temperature seldom rose high

enough to fuse the ore, and the resultant mass of iron would be mixed with scoriæ. It was, however, brought under the hammer and fashioned into a rude billet or bloom, being freed from some of its impurities in the process. By some such method as this the Romans treated the iron ores of Britain, traces of their operations having been found in the Forest of Dean and elsewhere. The scoriæ or refuse of numerous ancient bloomeries has since been re-smelted, as it usually contained a good deal of iron that they had not succeeded in extracting.

These elementary methods of separating iron from its ores were to be found in many different parts of the world, and are retained to this day in remote regions of Africa, Asia, and South America. In India and other tropical regions such as Burma, Borneo, and Madagascar, the natives devised a mechanical means of providing a forced draught for their furnaces. A loose plunger working backwards and forwards in a hollow bamboo—like the piston of a pump—furnished the blast necessary for the smelting of the iron.

Little progress was made either in the mining or the treatment of iron ore for many centuries. The ore was plentiful enough, but the methods of smelting and working were primitive and laborious, inefficient and wasteful, and as a result iron was comparatively scarce and costly, and steel even more so. Steel was only used where strength and sharpness were requisite, as for example in hoes and scythes, and, more especially, swords. William the Conqueror attributed his victory at Hastings to the superior weapons and armour of his men, and he raised the smith or sword-maker to high rank. That was the age of the sword, and certainly the artificers of that and later periods secured wonderful results when the nature of the appliances at their disposal is considered. The blades

of Toledo, Bilboa, and Damascus have never been surpassed for temper, keenness, and finish. By the exercise of great care and skill remarkable results were achieved, but with the faulty and inefficient smelting process of the earlier Middle Ages, neither uniform quality nor regularity of output could be depended upon.

In fact, from the remote times when men first smelted iron down to the fourteenth century, or just before Columbus sailed on his voyage to the unknown, little if any advance was made in the manufacture of iron. The distinctive product of the Middle Ages was undoubtedly the Catalan forge, which is said to have been introduced in the French Pyrenees as early as 1293. It was soon adopted and used in Catalonia, and is still in use in remote parts of Spain and other countries. The Catalan forge resembled in many respects the blacksmith's forge of to-day. The air blast was provided from a large pair of bellows, or preferably by means of a contrivance known as a *trompe*. This consisted of a pipe through which water was allowed to fall, carrying with it bubbles of air which escaped into an air-tight chamber or receptacle. There the air accumulated at a pressure derived from, and proportionate to, the height of the falling water. But if no water was available near his little mine of iron ore, the mediæval iron-smelter had the option of either carrying the ore to a place where water-power could be had, or of setting up his furnace near the ore-supply and providing the necessary blast with the aid of huge bellows worked by hand. Both methods were used, and heaps of clinkers, proofs of the labours of these early iron-workers, have been found high up on the slopes of the Pyrenees far away from any water.

The Catalan forge marked the beginning of a new epoch in the extraction of iron from its ores. The

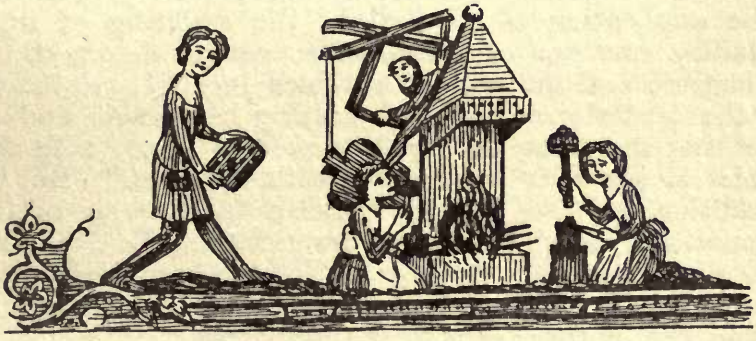
earlier iron-smelters had only been able to secure a comparatively small amount of wrought iron from the ore in a single operation. But with the introduction of the Catalan forge, and the subsequent increases in the power of the blast and the height and capacity of the furnace, the metal was at least partially carburized and fused. In melting, it was effectually separated from the gangue or ore, and so was run off as a crude form of steel. This was of little use to the iron-workers of those days, and a rude refining process was resorted to for the elimination of the hardening carbon. The metal was again placed in the furnace with charcoal and heated. The blast was directed over its surface, and so the carbon was burned out of the steel, leaving it as a quality of iron which was described by François as in general fibrous, hard, very malleable and tenacious, but not uniform in quality, having portions of steel in its mass.

The increasing demand for iron led to an increase in the size of the bloomery or furnace. It was found, however, that as the smelting furnace increased in height, the pressure and volume of the mass of ore and fuel retarded the ascent of the blast and interfered with the efficiency of the smelting. After a time buttresses were built inside the furnace to support the weight of the charge, relieving the central parts from the pressure, and thus allowing the free ascent of the blast. Improvements in the blowing apparatus followed, ensuring a better and more uniform quality of iron and an increased output. The ultimate outcome was a furnace which in all essentials except size was identical with the blast furnace of to-day.

The precise date of the adoption of a regular process of producing and casting molten iron cannot be satisfactorily determined. It was known to Georgius Agricola (1494–1555), the German mineralogist, for he

wrote: "Iron smelted from ironstone is easily fusible and can be tapped off. When the same, after the slag has been lifted off, is further heated to redness it becomes malleable, and may be worked under the hammer and drawn out."

As to the date at which the art of casting in iron applied to the production of useful or ornamental articles was first practised, some writers assert that ornamental castings were made in Sussex in the fourteenth century. According to the antiquarian Lower, as quoted by Dr. Percy, however, the first authentic record of casting in England was that of some cannon by Ralph Hoge or Hogge in 1543 at Bucksted (Bucksteed) in Sussex. "This founder," we are told, "employed as his assistant Peter Baude, a Frenchman, whom he had probably brought over to teach him the improved method."



ENGLISH IRON-WORKERS, *c.* 1350.
From a contemporary MS.

At what period the gradual evolution of the blast bloomery into the blast furnace became complete it is difficult to say. In all probability it was in the

early part of the sixteenth century, for we find that by the seventeenth century the art or craft of casting, which was a direct outcome of the increased efficiency of the smelting furnace, had reached a fair degree of perfection. During the reign of Queen Elizabeth there was a considerable export trade in cast-iron ordnance from England to the Continent.

Up to that time wood charcoal was the only fuel that had been used in the smelting of iron. The blast furnaces consumed great quantities of wood for this purpose, and in 1558 the cutting down of trees for the use of ironworks was prohibited in this country. As a result the number of furnaces in blast decreased by three-fourths and the output of iron diminished in like proportion.

Attention was at once turned to pit-coal, as the mineral fuel was then generally known, and James I. granted patents to several ironmasters, among the earliest of whom was Simon Sturtevant (1611), for the application of pit-coal in the smelting of iron. Dudley was one of the most successful among these pioneers, and his patent, obtained in 1621, related to "the misterie and arte of melting iron ewre, and of making the same into cast workes or barrs, with sea coles or pit coles in furnaces with bellowes." But in addition to the hostile criticism and even active opposition of the charcoal ironmasters, Dudley had to encounter and grapple with many practical difficulties, and his works were unable to produce more than two or three tons of iron per week.

Then came the idea of applying to coal a process analogous to that applied to wood in order to convert it into charcoal, and so make it more suitable for iron-smelting. The outcome of these experiments in charring, roasting, or partial combustion of the mineral fuel was coke. But here another difficulty arose. The

slower combustion of coke rendered a more powerful blast and a longer subjection to the heat necessary before success could be attained. Ignorance of the cause of failure prevented the adoption of coke until an increase in the height of the furnace prolonged the contact of ore and fuel and so partially solved the problem.

It was Abraham Darby—a descendant of John Darby, the Bristol malt-maker who brought Dutch brass-founders to England—who really solved the difficulties in the way of the adoption of coke as a fuel for iron-smelting. Dr. Percy quotes a description of Darby's experiments written by Mrs. Darby:

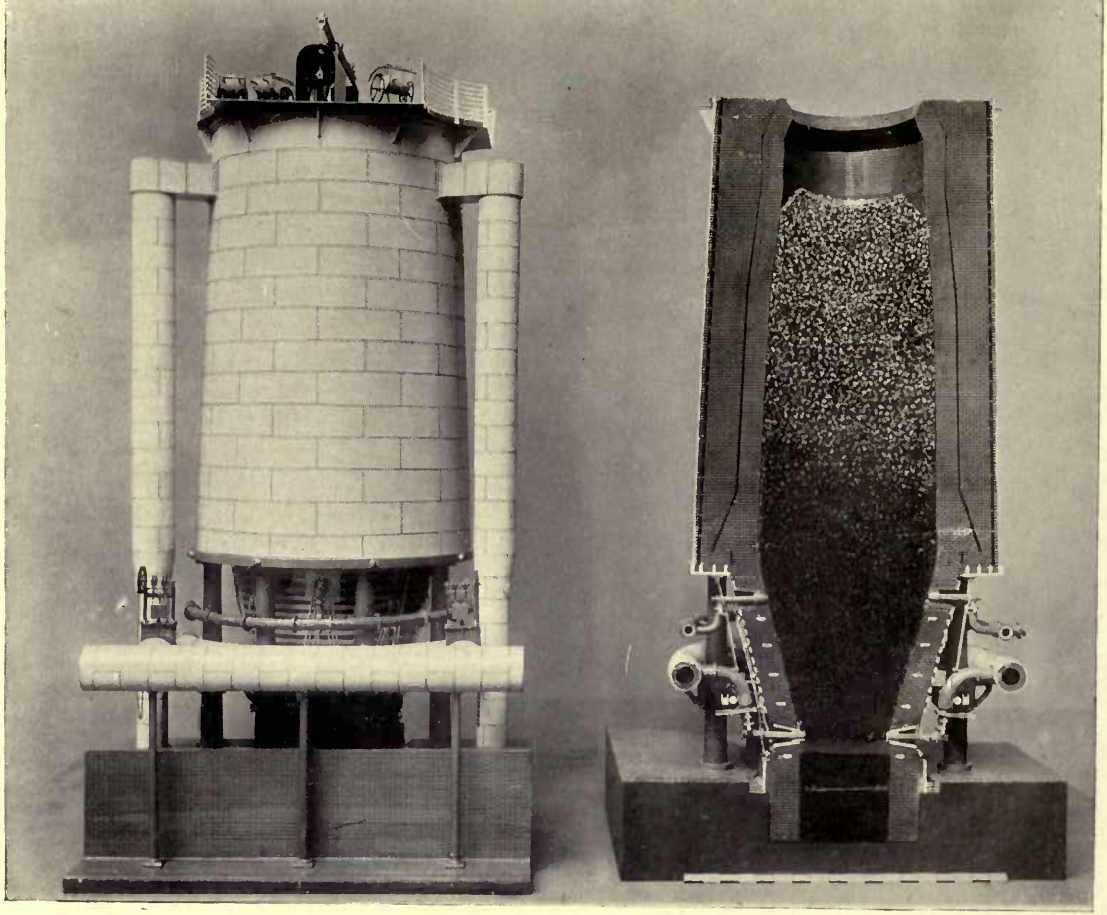
"Between 1730 and 1735 he determined to treat pit-coal as his charcoal-burners treated wood. He built a fire-proof hearth in the open air, piled upon it a circular mound of coal, and covered it with clay and cinders, leaving access to just sufficient air to maintain slow combustion. Having thus made a good stock of coke he proceeded to experiment upon it as a substitute for charcoal. He himself watched the filling of his furnace during six days and nights, having no regular sleep, and taking his meals at the furnace top. On the sixth evening, after many disappointments, the experiment succeeded, and the iron ran out well." Such were the beginnings of the modern coke-heated blast furnace.

About the year 1783 or 1784 Henry Cort of Gosport introduced the processes of puddling and rolling, two of the most important inventions that succeeded the evolution of the blast furnace. Puddling was a process long used for the production of malleable iron in quantities. The molten metal was run into the concave top of a reverberatory furnace heated by coal. There the liquid iron was puddled or stirred until the ebullition ceased. Exposed to the oxidizing influence of air and

flame, the carbon was eliminated and the metal became malleable. It was moulded into blooms and hammered to remove the slag, as of old. But by Cort's second process of rolling, the blooms were at once reduced to a useful and marketable shape. He was the first to introduce shaped and grooved rollers which pressed the white-hot iron into sheets or bars as required.

The importance of Cort's improvements in iron-working was only overshadowed by that of James Watt's steam engine. The coming of the steam engine marked a new era in the iron industry. It was applied to rolling, forging, and to the driving of improved blowing apparatus, giving a more powerful and regular blast. An apparently simple idea which was embodied in a patent taken out by Mr. J. B. Neilson, a Scotch engineer, in 1824, was destined to mark another epoch in the history of iron. This was neither more nor less than heating the air blast before it reached the furnace. Yet so much did this simple device increase the efficiency and economical working of the blast furnace that after its introduction three or four times the previous quantity of iron was produced with a fuel consumption of little more than a third.

Towards the middle of the nineteenth century the demand for more iron and cheaper steel grew more insistent, and was met by Bessemer with his boldly conceived and ingenious conversion process. The rationale of his method is simple. Tons of molten iron are run into great pear-shaped converters or retorts, and through holes in the bottom air is forced at high pressure. The oxygen of the air unites with the carbon in the molten metal and the heat of the burning makes the retort into a roaring furnace spitting flame. In twenty minutes this fierce blast has burned the carbon out of 20 tons of metal, converting it into malleable iron. The workman watching the flames, cuts off the



Sectional Model of Blast Furnace.

UNIV OF
CALIFORNIA

blast the moment the changing colour warns him that the carbon is gone. Then an alloy containing carbon is carefully added to reconvert the metal into steel of an exact carbon content as required. In 1878 Messrs. Thomas & Gilchrist discovered that by simply lining the converter with limestone they were able to eliminate the objectionable phosphorus.

These repeated improvements, which revolutionized the manufacture of iron and steel, placed Britain in the first place among the iron-producing countries of the world. There were, too, other causes which helped to give this country a long lead in the race for supremacy. First there was the fortunate juxtaposition of the coal-fields and the iron-ore deposits, and their nearness to the cheap transport by sea. Then there was the long era of peace which left England free to develop her industries, while wars and unrest in other countries, notably Italy, France, Germany, and the United States, both prevented competition and increased the demand for guns and other warlike material in which iron plays so large a part. All these causes combined to make Great Britain during the latter half of the nineteenth century the ironmaster of the world.

CHAPTER XIX

A WORLD-WIDE ORE

GEOLOGISTS and astronomers tell us that there is more iron in the world than appears on the surface—that in fact a great part of the bulk and mass of this earth of ours consists of iron in some form or other. It is, however, with the surface or thereabouts that we, as superficial beings, are immediately concerned, and when we come to examine the earth's surface we find that although iron, as compared with other metals, is comparatively plentiful, it is scattered round the world in the most erratic and elusive fashion. Much of this peculiarity of distribution is doubtless due to the fact that iron is readily oxidizable when exposed to the air, and still more when subject to the action of water.

Since the beginning of time rain has fallen intermittently upon most of the earth's surface, washing away, amongst other things, minute quantities of iron into the rivers, lakes, and seas. Most of it is lost in the ocean, but in certain lakes and bodies of water in various parts of the world there are minute organisms which have the power of causing the iron in the water

to be deposited in the form of a fine powder on the bottom of the lake or bog. Thick deposits of this form of iron, which is called bog or lake-ore, have been found in Sweden, America, and elsewhere. But this illustrates only one phase of the age-old process of dispersal and distribution of iron over the earth's surface. An even more ancient process is that which resulted in the formation of somewhat similar deposits among the coal measures in England, America, and many other parts of the world. Possibly the most potent factor of all in this redistribution of the world's supplies of iron has been the fact that when water holding iron in solution comes into contact with lime or limestone it immediately deposits the iron. This accounts for the presence of large beds and pockets of iron ore which are so frequently found in contact with limestone.

The ores of iron are numerous and diverse in character and composition. They may, however, be grouped into three great classes, of which the first and most important are the oxides or combinations of iron and oxygen; then the carbonates or combinations with carbon; and lastly the various combinations with sulphur. The richest of the iron oxides is magnetite or magnetic iron ore, which in its purest state contains over 72 per cent. of iron. It is the most valuable of all the ores of iron, and much of the famous Swedish iron is made from it. Then there are the hæmatite ores, varying in colour from a deep red to a dark grey, which are almost as productive as the magnetic ores, often yielding 70 per cent. of iron. The red hæmatite is one of the oldest and most widely distributed of iron ores, having been worked in Spain and Elba from ancient times, and more recently in Cumberland, Saxony, Bohemia, and various parts of America.

The limonite or watery oxides include the bog ores and some others of less importance. As they almost invariably contain a proportion of water the percentage of iron may not exceed and seldom approaches 60. Siderite, or carbonate of iron, is also called spathic ore. Clay-ironstone is an impure variety with an admixture of clay, and when found among the coal measures, as is frequently the case in England, it is called " blackband." Iron pyrites or bisulphide of iron, probably the most abundant of all ores of iron, is unfortunately of little use in the manufacture of the metal on account of the large admixture of sulphur it contains.

Native or metallic iron is seldom found, probably by reason of the irresistible tendency of iron to oxidize and rust away. Most of the masses of iron that have been discovered from time to time on the surface of the earth are of meteoric origin. They invariably contain a high proportion of iron—from 80 to 90 per cent—the remainder consisting of nickel. A meteorite from Texas which is preserved at Yale University weighs 1,635 lb.

Great Britain early took the lead among iron-producing countries, and kept it for a long time, culminating with the period of greatest prosperity during the nineteenth century. Many factors combined to produce this result, and none more so than the advantageous position of the ore deposits near the coal-fields, and close to navigable waterways and the coast. These valuable ore beds extend from Northamptonshire northwards through Staffordshire, Lancashire, Yorkshire, and Cumberland, and into Scotland. About two-thirds of the ore mined is siderite or clay-ironstone.

One of the oldest and most historic centres of iron-mining is the Forest of Dean. Under the coal measures of this small, detached coal-field, and permeating some of the other strata, are the deposits of ore which have

made the district an iron-producing centre. There are also deposits in the upper limestone which outcrops round the edge of the coal basin. The grey ironstone formation in which the principal iron-ore deposit occurs, consists of a layer of fissured limestone of an average thickness of 25 yards. The caverns or "churns" in the limestone are full of iron ore, so that the deposits are neither even nor continuous, but are connected with each other by "leaders" or thin, irregular veins. The churns are not far apart, so that when the limestone is reached the mining of the ore is neither uncertain nor precarious. One of these churns or pockets of ore was 350 yards long, 14 yards high, and 12 yards wide, and is estimated to have yielded 60,000 tons of ore. One of the most remarkable of these churns is known as the "Devil's Chapel," at the Old Park Iron Mines near Bream.

Large deposits of ironstone have been found and worked in the carboniferous limestone of Lancashire and Cumberland. Some of the beds probably represent original deposits of ferruginous mud on the ancient sea-bottom, while the cavities in the limestone filled with iron ore point to a later filling by the infiltration of water, after it has passed through overlying ferruginous beds.

A considerable proportion of British ore is got from the coal measures. The black-band ironstone of Staffordshire, Lancashire, and Scotland is found near the summit of the Upper Coal measures. There are also clusters of clayey ironstone beds which lie in the lower productive coal measures of Staffordshire, Warwickshire, and North Wales. Then there are the series of beds of ironstone that are found in the Gannisters of North Wales and South Staffordshire.

The most famous iron-mining area in Great Britain is the Cleveland district, which occupies the north-

eastern portion of Yorkshire, bounded on the north by the Tees, and by the sea on the east. The pioneers of the Cleveland iron industry were Messrs. Bolckow & Vaughan, who in 1851 erected three furnaces at Middlesbrough. Other manufacturers soon followed suit, and what had been a thinly populated agricultural district became a great industrial area. Having for fuel Durham coke, which is said to be the best in the world; possessing large resources of ore which are uniform and easily smelted, if not rich; and being convenient for shipment, Cleveland advanced rapidly until it became for a time the chief iron-producing centre in the world.

The Cleveland ironstone occurs in large masses or beds which are of uniform composition over large areas. It is an inferior form of clay ironstone containing only about 33 per cent. of metallic iron. The ore is divided by bands of shale and pyrites into several beds, and where best developed it has a thickness of over 20 feet. The two principal beds are called respectively the *pecten* and the *avicula* seams, from the fossil shells which characterize them, the nodules of iron ore often replacing the organic matter of the fossil remains. The usual colour of the ore is a dull bluish green, caused by the presence of silicate of iron. The main bed reached its greatest thickness at Eston, where the yield per acre was estimated at 50,000 tons. The Lower Cleveland bed of iron ore near Middlesbrough is still the most important in Great Britain. It is from 10 to 17 feet thick and contains 30 per cent. of iron. In the year 1905 the Cleveland iron-mines produced 41 per cent. of the total British output of iron.

The brown hæmatite ore beds of Northamptonshire were opened up about the same time as the Cleveland deposits, and soon produced iron in considerable quantities. More recent is the development of ironstone-mining

in the north-west corner of Lincolnshire. This bed, which is closely allied to, although lying a little lower than, the Cleveland main deposit, averages about 27 feet in thickness.

Many of the iron-ore deposits of Great Britain have been or are being rapidly exhausted. The production of British ore is consequently declining. In 1882 it was 18,031,957 tons, while in 1905 it had fallen to 14,590,703 tons. An additional 7,344,786 tons had to be imported from abroad to meet British demands, over three-fourths of this being derived from the mines of Spain.

Crossing the Channel into France, we find that that country has a fairly plentiful supply of iron ore both in the coal measures and in the other strata. In the upper part of the valley of the Moselle, about Nancy, there is an important bed of ironstone which apparently corresponds with that of Northamptonshire. Between layers of marl the ore occurs in small grains cemented together by lime and clay. The percentage of metallic iron ranges from 20 to 35. The greater portion of the iron ores used in France are, however, derived from the coal-fields of the country, but the ironstone beds of the coal measures do not attain the magnitude or importance of the corresponding English deposits.

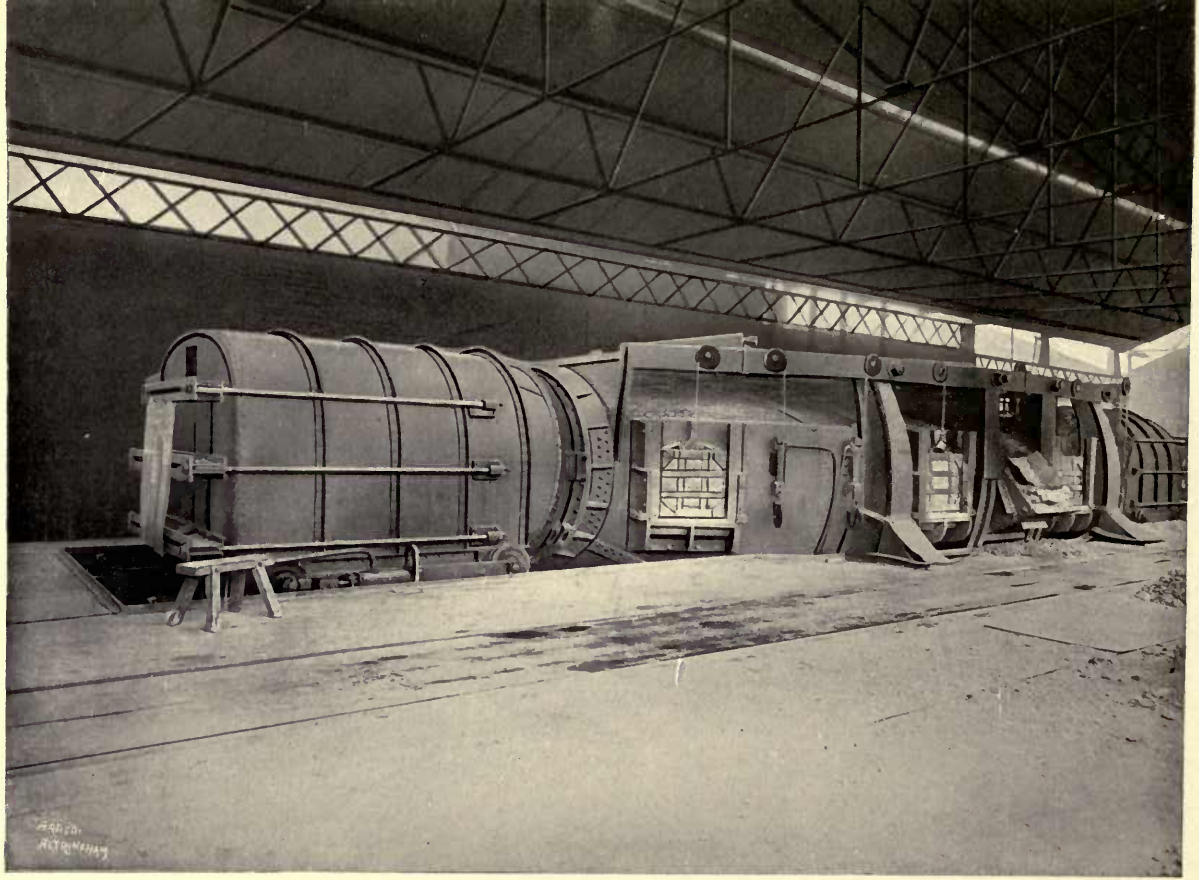
Germany derives about two-thirds of her iron supply from the great "Minette" series of ore deposits of Luxembourg and Lorraine, which is one of the most important in Europe. The brown hæmatite ore which is known as "Minette" occurs in the form of oolitic grains about the size of a pin's head, cemented together by siliceous material. Despite the fact that the ores contain on an average little more than 30 per cent. of iron, these "Minette" deposits are valuable on account of their great size. They extend through a

district 40 miles in length and 8 miles wide, and in some places are nearly 60 feet thick. Valuable deposits of black-band and clay-carbonate ores are found between the seams of the Ruhr coal-field. The iron-ore deposits of Nassau are interesting because they are found in a position geologically unique. They lie in hollows of porphyritic rock and are consequently irregular in their occurrence. The carbonate iron ores are also found intermingled with the lead and other ores on both sides of the Erzgebirge, that is to say in Bohemia as well as in Saxony.

Some of the finest and purest iron in the world is derived from the ores of Sweden, particularly the magnetic oxides, in which that part of Scandinavia is peculiarly rich. At Dannemora, 55 miles from Stockholm, there is a large and important deposit of magnetic iron ore which occurs in a series of slate beds. It extends for 7,000 feet, or over a mile, in length, is 600 feet wide and 20 feet thick, and has been worked downwards for about 1,000 feet. The beds slope steeply and the iron-ore deposits assume a roughly flattened cylindrical shape.

In other parts of Sweden, where, owing to the action of the elements, the surrounding rocks have been weathered and worn away, great masses of ore assume the form and character of iron mountains. A well-known example occurs in the ore mass of Gellivara in northern Sweden, just within the Arctic Circle. This mountain is between 3 and 4 miles long and consists for the most part of masses of shining specular ore mixed with magnetic oxide. The principal deposit is from 100 feet to 500 feet in thickness. Near Gellivara are the Kirunavara and Luossavara mines, in which is a great body of ore 11,000 feet long and 500 feet across.

The iron ores of Sweden are especially valuable for the manufacture of the finer qualities of iron and



Wigan Coal and Iron Co.

STEEL WORKS: METAL MIXER (CAPACITY 250 TONS).

DUKE

steel. The ores contain from 30 to 71 per cent. of iron, or an average of 50 per cent. The chief deposits worked in southern Sweden—Perseberg, Norberg, Grangesberg, and Dannemora—extend in a northerly direction from the north end of Lake Wener.

Bog or lake ores are found in the lakes of southern Sweden in beds which sometimes reach a thickness of 2 feet. These ores contain a good deal of phosphorus and are therefore not so suitable for the manufacture of malleable iron as for the making of the finer kinds of cast iron. The lake ores are found in large beds in the shallow portions of the larger lakes. The collecting of the ores formerly provided employment for many people in the province of Smaland, and their methods furnish a unique chapter in the story of iron-mining. It has been thus described:

"Towards the end of autumn, or when the lakes have become ice-bound to the depth of two or three inches, the collector sets out on his search. For that purpose he makes little holes in the ice along the slopes of the shallows. Through these holes he puts down a long pole, with which he gently strikes the bottom, and partly by hearing, partly by the sense of feeling, ascertains whether any ore or not is to be found in the place; but long practice is needed in order to pursue the work with success.

"The extent of the layer being known, the collector marks the boundaries of the same by means of little twigs stuck into the ice to prevent others from encroaching on his territory, now considered as lawfully acquired property. In this manner the collector marks out as many places as he intends to work during the winter, and proceeds, upon the ice getting strong enough, to collect the ore, this being performed in the following manner: At the outer boundary of the marked 'claim,' a round hole of about three feet in

diameter is cut through the ice, and through this hole a riddle or perforated iron plate fixed to a long pole is put down, and sunk to the bottom of the lake. The next tool consists of an iron rake about two feet broad, also fixed to a pole. With this rake the collector, by means of certain manipulations, collects the ore in a heap at the bottom, and by means of another rake about six inches broad he fills the riddle, which is then got up, and its contents, consisting of ore, mud, clay, and sand, piled into a heap on the ice. In order that the ore may be separated from these impurities, the mass is put into another iron riddle, and by sinking this two or three inches below the surface of the water and giving it a rocking motion, the collector sifts as it were the dirt from the ore, and piles the latter on the ice, whence it is brought to the nearest blast furnace. Two labourers are generally associated, the one being busy collecting and the other washing the ore. If the ore is tolerably plentiful, a man generally gathers from half a ton to a ton in a day, all depending of course as well upon his skill as upon the quality of the ore and the materials composing the bottom; for if the latter consists of mud, the gathering is much more easily performed than if the ore is resting on clay, stones, or sand. The ore happens sometimes to be covered with a thin layer of mud, in which case great skill and ingenuity is required, not only to discover it, but also to uncover the same so as to make it possible to be got up."

According to Mr. C. W. Sjögreen, the Swedish expert, who believes the lake ores to be of infusorial origin, they are reproduced in places where, years before, the supply had been exhausted.

With the demand for hæmatite ores, which increased rapidly after 1860, owing principally to the introduction of the Bessemer process, came a marked

development of the iron-mining industry of Spain, particularly on the north coast. There rich deposits of ore are extensively worked, the output being mostly exported from the great iron-ore port of Bilbao. From Bilbao numerous rusty-looking tramp steamers sail regularly for various European ports, but chiefly for those of Britain and Germany, the two great iron-producing countries which are also large importers of ore. The great German concern of Krupp owns its own iron-mines in the Biscay district. The mines of Biscay are situated between 15 and 20 miles from Bilbao. Some of them consist of open excavations, and of levels driven into the sides of the mountains, but latterly they have been worked by means of shafts and underground workings. The three districts of Biscay, Santander, and Guipuscoa, of which Bilbao is the natural outport, combine to form one of the most important iron-mining areas in the world, containing as they do over 200 iron mines and employing many thousands of men. The ores are rich hæmatites which vary in colour from the red or *rubio* to the lighter yellowish-brown ore.

The demand for Spanish hæmatite ores has been so great in recent years that the mines of the Bilbao district, which had hitherto furnished by far the greater proportion, have been partially worked out, or are producing inferior ore. There are, however, underneath the hæmatite large deposits of spathic ore which have not yet been fully developed. The steady demand too has resulted in the opening up of deposits of iron ore at other places, notably Oviedo and Corunna. In the opinion of some experts the iron ores of the south of Spain, and especially of the provinces of Almeria and Murcia, will play a large part in the future of the iron trade of Europe.

The North American continent is well provided

with natural resources in the shape of iron, important deposits of iron ore being found in Canada, Nova Scotia, and more especially in the United States.

The iron ores of Canada possessing economic importance are magnetite, hæmatite, and limonite, of which the first named, found in the Laurentian rocks, is the most abundant. Deposits of magnetic ore have been located and worked at Hull, Newborough, and South Sherbrooke; of hæmatite at McNab, Sutton, and Brome; and of bog ore on the shores of Lake Erie. The Nova Scotian deposits have long been known to be of considerable magnitude and importance. The ores too are of great variety, ranging from the comparatively recent bog ores of Bloomfield to the glittering specular ores of the Upper Silurian formation in the Acadia Company's mines at Londonderry. In the carboniferous limestone at Sutherland's Brook and French River, Pictou, there is a large bed of spathic ore of which the middle or "main" bed is from 6 to 10 feet thick. When protected from weathering the ore is of a grey colour with a pearly lustre. Farther westward, geological surveys have revealed the existence of ferruginous deposits right away across Canada to British Columbia. The rich magnetites and hæmatites found on the Canadian side of the Great Lakes are however exported to the United States owing to the absence of fuel for smelting purposes.

The United States are rich in the possession of extensive deposits of the ores of iron, deposits so abundant that they have placed the States in the forefront of iron-producing countries, a position that will almost certainly be long maintained. All the three great common groups of ores are well represented. The magnetic ores are worked in New England, New York, and New Jersey; the hæmatites in Pennsylvania, New York, New Jersey, Connecticut, Tennessee, and

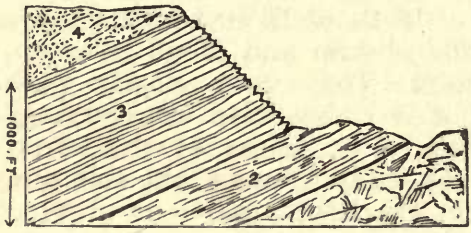
Missouri; and the clay ironstones among the measures of the great coal-fields.

The most interesting and important deposits are the westerly ones of Missouri and Michigan. The last-named ore-beds are situated near the shores of Lake Superior and form a series of the greatest supplies of ore in the known world. There are numerous and largely worked beds of brown hæmatite in Missouri, but the most striking and interesting deposits are those of Iron Mountain and Pilot Knob. The first of these is a dome-shaped hill rising to about 200 feet in height. It is composed of red porphyry, and forms the end of a ridge of similar material. The surface of the hill was covered to a depth of 15 feet with boulders of almost pure peroxide of iron and of all sizes up to a weight of many tons. They were closely packed together with a bright red clay, also iron-bearing, which filled the interstices. The source of these iron boulders is uncertain. Possibly they are the sole remains of some igneous rock, the lighter portions of which have been disintegrated and washed away. Pilot Knob is a conical shaped hill some 650 feet high. The beds of iron ore, which are of a hard specular variety, alternate with siliceous matter and have a thickness of about 200 feet. They have a somewhat slaty structure which distinguishes them from the ores of Iron Mountain. The Pilot Knob deposits are of considerable width but are not continuous over a very large area.

The Lake Superior region is not only the greatest iron-producing area in the United States, but one of the greatest in the world. The deposits of ore occur as an immense succession of thin beds in the slaty and hornblendic rocks. These iron-bearing slates occupy a belt from 6 to 20 miles wide, and stand out boldly as a successive series of cliffs from 50 to 150 feet high, like a range of iron hills. This remark-

able iron zone extends from the shores of Lake Superior right away into Wisconsin and Minnesota, a distance of 150 miles. The iron-bearing beds are not continuous over the whole of this great length, but occur at frequent intervals in areas varying from 200 yards to over a mile in length.

Speaking generally, the deposits consist of peroxide of iron mixed with much earthy matter. They occur as thin alternating beds, some layers not exceeding a quarter of an inch in thickness, but consolidating at times to form beds of great thickness. In its purest state the ore is a compact specular ore with crystals



GEOLOGICAL POSITION OF IRON ORES OF LAKE SUPERIOR.

of magnetic oxide profusely disseminated throughout. The proportion of iron averages about 55 per cent. On the Cleveland property the deposit is 1,000 feet thick and one mile in length, and it is said that the supply of iron ore there alone is sufficient for the supply of the whole world for a long time to come.

The iron ores of the Lake Superior region appear to have been deposited at about the same period as the material of the slates. The deposits were first worked about the year 1855, in which year the production was only 1,457 tons. In 1899 the mines of the Lake Superior area furnished fully 80 per cent. of the whole of the iron ore produced in the United States, which,

when reduced to pig-iron, amounted to the huge total of 25 million tons.

Iron-mining has been pursued in India from a very ancient period, but usually in decidedly primitive fashion, so that the greater portion of the deposits, both old and more recently discovered, remain as a sphere for the application of modern methods and European energy.

Valuable beds of magnetic ore have been found near Salem in the Madras Presidency. The deposits are unusually numerous, thick, and productive. On the conical hill known as Kunjamullay, for instance, which rises about 1,000 feet above the surrounding plain, three great beds of magnetic ore crop out, each about 50 feet thick. The ore is of good quality, somewhat resembling Swedish ore.

The rich ores of Central India, on the other hand, are principally found as hæmatites in the Bijawar or lower strata, while the ironstone shales of the Raniganj coal-field belong to the carboniferous period. In the vicinity of Chandiwick in the Nerbudda Valley and elsewhere there are beds of nodular and decomposed ore which, when fuel was more abundant, were worked by the natives. Their primitive methods have, however, been displaced by latter-day enterprise, which bids fair to make India take a high place in the list of iron-producing countries in the Far East.

In Australia deposits of all classes of iron ore are to be found. The chief iron-producing colony is New South Wales, and one of the most notable ore-beds is that of Wallerawang, 105 miles from Sydney. There there are two deposits, one of magnetite and one of hæmatite, and both of good thickness. As in so many other instances, good beds of iron ore have been located in the coal measures, where their intrinsic value is increased owing to the fact of their proximity to the

fuel by the aid of which the ores are smelted. In Queensland clay ironstone is stated to occur near to coal; Victoria yields brown hæmatite; and South Australia possesses deposits of iron ore but no coal. In New Zealand many different varieties of iron ore have been discovered, the most remarkable of which are the "black sands," like those of Taranaki.

This brief description of the deposits of the ores of iron in different parts of the world will have afforded some illustration of the different ways in which this metallic mineral occurs. It may be taken as a general rule that the magnetic ore is of the most ancient origin and is found in the older rock; the compact and crystallized hæmatite in the carboniferous limestone, and the more clayey and earthy varieties in the upper formations. Fortunately for man, iron is not only more generously distributed geographically speaking, but is found in a greater variety and range of strata, than any other metal.

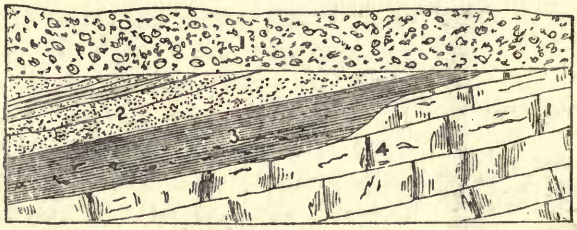
CHAPTER XX

IRON-MINING AND THE AGE OF STEEL

UNLIKE all other metallic ores, those of iron are not restricted geographically to hilly regions or geologically to rocks lying below the level of the coal measures. Fortunately for an iron-using world the presence of a deposit of iron ore in depth is frequently indicated by traces of the mineral on the surface. Science has also come to the aid of the seeker after iron and has enabled him by means of a dip-needle to locate important deposits of magnetic iron ore in Sweden and America.

Practically speaking, the mining of iron ore differs in few essential particulars from that of any other metalliferous mineral. Still, the ores of iron occur in so many different forms and in so many different kinds of rocks that their extraction affords examples of several varieties of mining. In the case of deposits like the British beds of the Forest of Dean, mining methods have to be adapted to local conditions. For the most part the ore in the peculiar "churns" in the fissured limestone yields readily to the pick. The churns are invariably connected by means of veins or leaders. The ironstone miners have a saying that "The smaller the leader the larger the churn."

While in some places open workings are feasible, the ores that occur at any considerable depth are extracted by regular mining, the arrangement of which naturally depends upon the conformation and distribution of the deposit. In the hæmatite districts of Lancashire and Cumberland, the red ore is met with in irregular pockets in the limestone. A typical example of these deposits is the Old Park Mine, belonging to the Barrow Hæmatite Company. The ore



SECTION OF HÆMATITE DEPOSIT AT PARKSIDE, CUMBERLAND.

body was 450 yards long, 250 yards broad, and of great depth. The ore has been worked since 1850 by means of levels which are driven in the adjacent limestone at intervals of 10 fathoms, a lower level being driven as soon as the one above is worked out. The workings have been opened out in 9-feet sections by the pillar-and-stall method, as employed in coal-mining.

The Cleveland beds of ironstone are also largely worked on the pillar-and-stall system. After the necessary roads or passage-ways have been driven through the ore, and ventilation has been provided for by cross-cuts, a solid square section of the bed is excavated by degrees. The process is continued until the pillars are cut through and partially removed—until in fact all except the side pillars are eventually taken

away. As soon as one portion of the mine is exhausted the pillars are removed and the roof of the workings is allowed to fall in behind the miners. A good deal of timber is used in the temporary support of the roof as the workings proceed.

Just as the mining of iron ore differs little from that of other metallic ores, so there is slight variation in the mining of similar kinds of iron ore in the various great iron-producing countries of the civilized world. The United States of America, however, provide an example not only of a unique series of deposits of iron ore in the Lake Superior region, but of mining methods of a highly specialized character. Some of the ore-bodies are so conveniently situated that they can be operated by open workings, the ore being excavated by steam shovels in a fashion similar to that which most of us have seen in use in the excavation of a canal or railway cutting. The ore is loaded into freight-cars or wagons which are then taken direct to the upper lake ore-docks from 10 to 100 miles away. From the high level of the railway the ore runs down chutes into great ore-bins on the wharf below, thence through more chutes into the hold of the ore-steamer in the lake alongside. This gravity loading enables the ore to be transported and conveyed with the minimum of time and labour, and therefore cost.

The ultimate destination of all iron ore is, of course, the blast furnace, but before it is ready for smelting the ore has usually to undergo some kind of preparation and treatment, which may be given at the mine or at the furnace, but must necessarily be of an inexpensive character. The ores are almost invariably mixed with earthy and foreign matter, and are treated in a variety of ways.

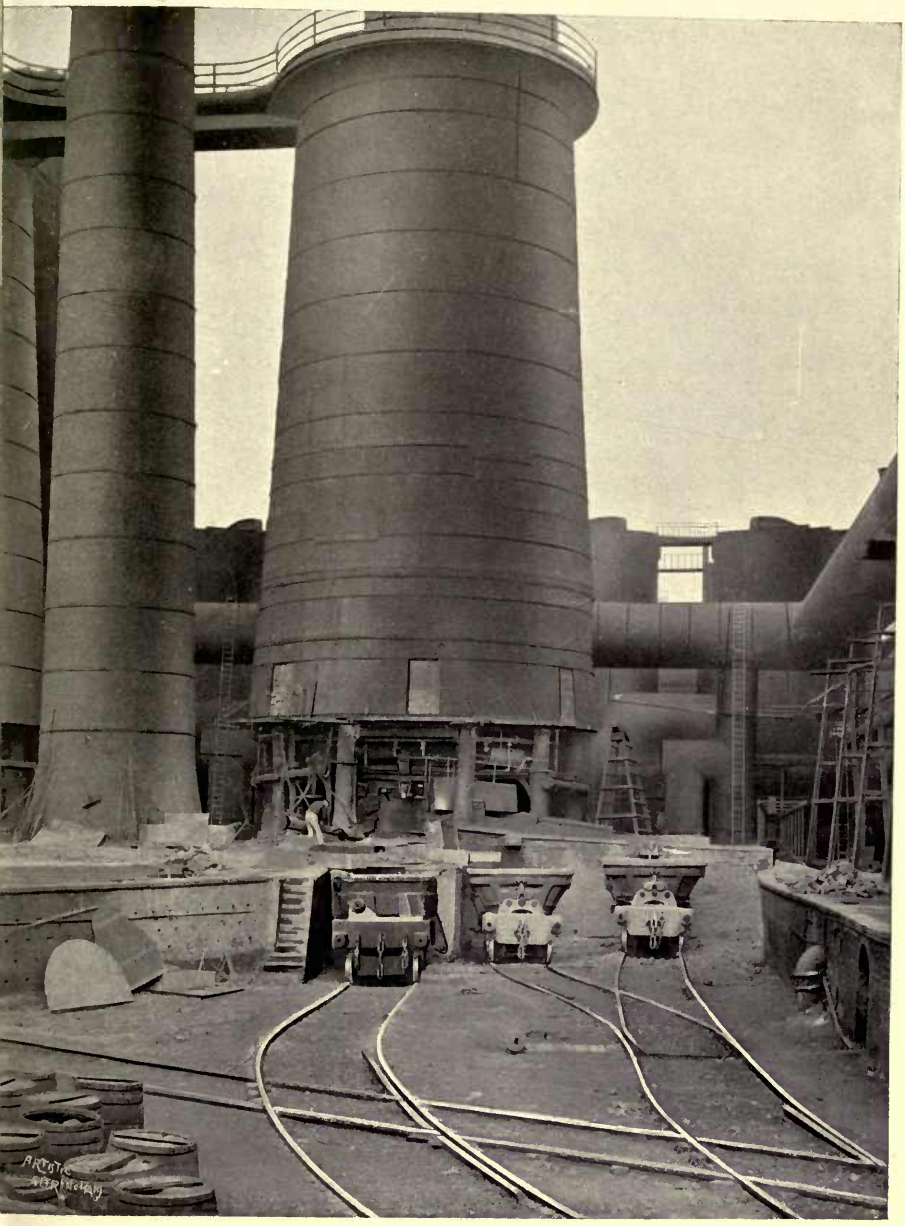
The oldest and simplest method was to have the pyrites and stones picked out by hand, leaving the

good ore. When the foreign matter is soft and friable, like clay for instance, the ore mass is washed or subjected to the action of running water. This process was formerly much used in the American states of Virginia, Georgia, Alabama, and Tennessee. Some kinds of ore, such as that having an admixture of shaly matter, is simply exposed to the action of the elements, so that the frost and rain will break up the shaly matter, render it more friable, and so facilitate its separation from the ore. The period allowed for exposure or weathering varies from three months to three years.

Another important phase of ore-treatment is that known as calcination. This process is utilized to dry the ore preparatory to smelting, but is more particularly applied to the sulphide ores, as by no other means can the sulphur be driven off. The heat of the calcining kilns, which are generally fired by means of the waste gases produced by the blast furnaces, causes the sulphur to be given off in acrid fumes. The ore is thus converted into an oxide and can then be treated in the ordinary way. Roasting was formerly carried out in heaps in the open air, but except in the case of "black-band," which, being bituminous, provides its own fuel, this was found to be inefficient and wasteful.

Still another device for the sorting of ore is applicable only to magnetite. This valuable ore is, as we know, unique among the ores of iron in that it is attracted by a magnet like iron itself. Advantage has been taken of this quality to apply magnetism to the separation of the ore from impurities. The ore to be concentrated must be in a fairly fine state of division. The general principle of the magnetic ore-separators or concentrators, which have long been used in the Swedish and American magnetite fields, is to have a revolving drum containing powerful electro-

UNIV. OF CALIFORNIA



Wigan Coal and Iron Co.

BLAST-FURNACE, KIRKLESS IRON AND STEEL WORKS.

APPROVED

magnets acting on a stream of finely crushed ore. Magnetic concentration effectually separates the pure metallic particles from the gangue and increases the intrinsic value of the material.

Some of the impurities mentioned, such as water, earth, and stone, simply adulterate the ore—make it "leaner," as it is called—and increase the average percentage of waste. The other more intimately mingled chemical compounds, such as sulphur, phosphorus, and titanium, have, however, a deleterious effect on the quality of the iron itself. A certain proportion of sulphur can, as we have seen, be removed by calcination. Phosphorus is more refractory, and a very small quantity—even one pound weight in 1,000 lb. of iron—would make the metal useless. For all practical purposes phosphatic ore was long considered valueless.

The scope of this story of the iron-mines does not permit of more than a brief concluding reference to the marvels of modern metallurgy and the wonderful equipment of the great works which transform the crude ore by a series of titanic processes into the many forms of iron and steel which enter so largely into the work of the world. The central feature of the modern steel-works is the blast furnace—a wonderful and fearful erection. These swart, iron-bound towers, some of which are 100 feet high, are doubtless familiar to the dwellers in industrial districts, but the only intimation of the terrible roaring furnace within is the jet of flame that blazes night and day, consuming the waste gases :

> "As a cresset true that darts its length
> Of beamy lustre from a tower of strength." *

* Wordsworth.

This great iron stack is lined with non-fusible material, and into its fiery throat are fed alternately small wagon-loads of coke and iron and limestone, while from orifices at the bottom there flow two incandescent streams of molten material—one the indispensable iron, the other the useless slag. The metal is run into moulds which form the familiar pig-iron.

Coke, the usual furnace fuel, could not generate sufficient heat, even assisted by the powerful hot blast, to separate the iron completely from the ore. The limestone, however, acts as a flux, greatly reducing the melting temperature, and helping to remove the impurities, with which it combines to form slag. When the ore fuses and melts, the molten iron sinks to the bottom, and the liquefied slag follows suit. Fortunately the slag is considerably lighter than the iron. The latter is run off at a low outlet after the slag has been drawn off at a higher level.

The blast of air is forced into the furnace at a pressure of from 8 to 20 lb. per square inch and at a temperature of from 800° to 1,100° Centigrade. This intense heat is imparted to the air blast by the gases given off by the furnace, and serves in turn to accelerate the combustion therein. The air blast is injected into the furnace near the bottom through pipes called tuyeres, which are cooled by constantly flowing streams of water to prevent their melting.

Great and far-reaching changes have taken place in the manufacture of iron, and more especially steel, during the last generation. All the resources of modern science and the inventive skill of trained minds have been requisitioned. But in mining—the " Robber Industry "—natural resources are the deciding factor, other things being equal. In the iron industry the outcome has been that the " workshop of the world " has been removed from one side of the Atlantic to

the other, and that the United States replaces Britain as the greatest of iron-producing nations.

With the great impetus given to the iron industry after the introduction of the Bessemer process, the resources of the British ore deposits became less and less able to keep pace with the demand. As the Cleveland ores declined in quantity the furnaces of the district were gradually changed over to supplies of Spanish ore, which could be brought cheaply from Bilbao. The Cumberland and Lancashire iron-mines—which between 1870 and 1880 had an annual output of 2,000,000 tons, a large part of which was sent to America in the form of rails—also had to follow suit.

In the comparatively short time that has since elapsed the world has witnessed a tremendous change, amounting almost to revolution, in the sources of supply, and the mining and manufacture of iron. Within the brief span of thirty years American resources have been developed and American methods been reorganized with such amazing rapidity that the United States has already long outstripped all competitors. Several factors have jointly brought about this phenomenal development. In addition to the natural advantages of the almost inexhaustible supplies of fuel in the shape of coal and natural gas round Pittsburg and elsewhere, and the immense deposits of ore in the Lake Superior region, there have been and are the imperative and growing demands of a comparatively new and rapidly expanding commonwealth, with its many industries protected by a high tariff.

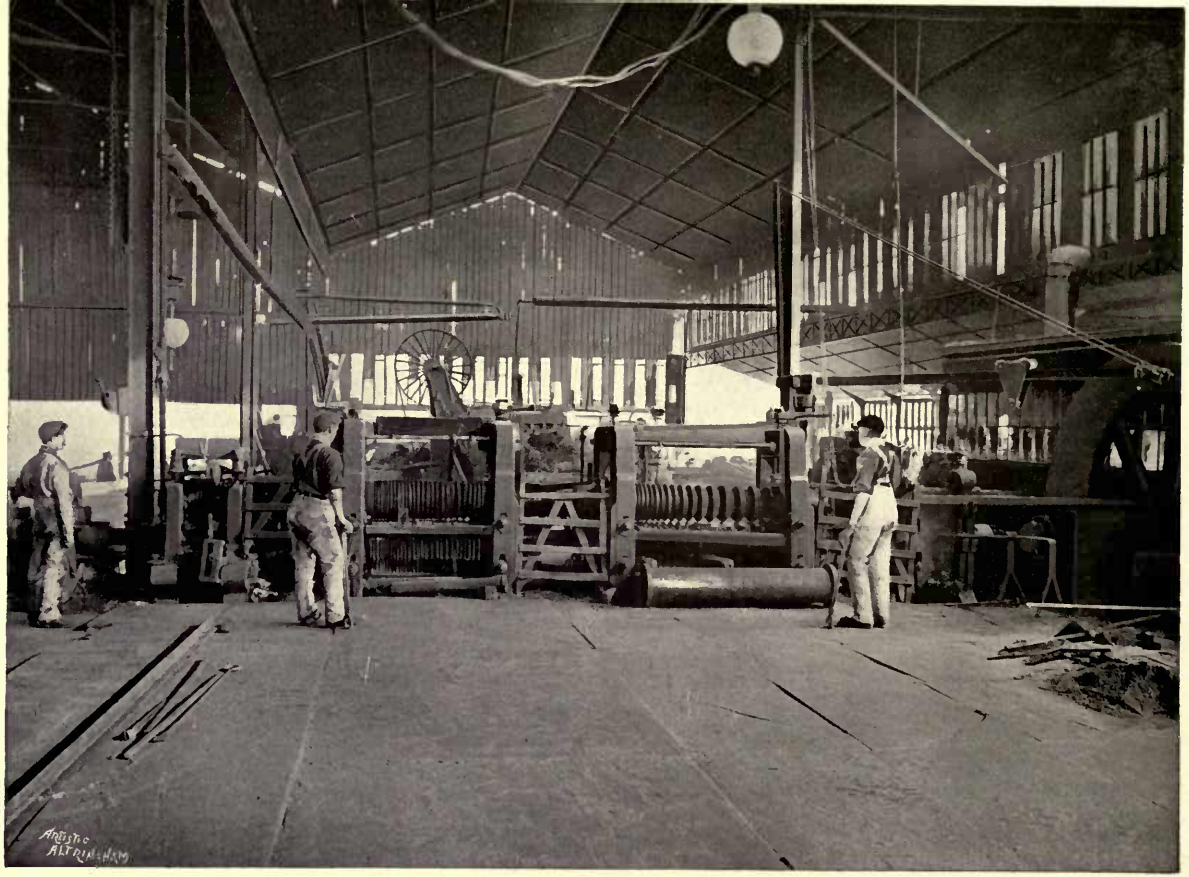
There have, of course, been difficulties in the way of this remarkable progress in the iron industry of America, but they have been overcome by foresight, ingenuity, and organization. First of all, the coal of Pittsburg and the iron ore of the Lake Superior region were 1,000 miles apart—nearly as far as Middles-

brough and Bilbao. As the smelting plants were already in being at Pittsburg for the treatment of the poorer local ores, the problem was primarily one of cheap handling and transport. The great steel concerns built or acquired their own steamers, railways, and rolling stock. Labour was scarce, expensive, and uncertain. The most elaborate and ingenious machinery was installed to replace it. Wonderful machines that could unload the ore steamers at the rate of nearly 2,000 tons an hour were set up at the lakeside docks, loading the ore into the railway wagons or tipping it into the ore-heaps which keep the furnaces going in the winter when the Great Lakes are frozen up and navigation is impossible.

After its thousand-mile rush to Pittsburg, the ore is transferred, after weighing, to the store bins of the blast furnaces. Formerly when the molten metal left the furnace it was cast into pig-iron, not by hand but by machinery. But this casting and cooling process is now considered superfluous. The iron is run into great portable ladles holding 25 tons, which are run into the steel-works and dumped into a great mixer. From the mixer the molten metal is filled into the Bessemer converters and so is made into steel and dealt with as required.

It is a fascinating story, could one dwell on it, this triumph of mind over matter, this materialization of the spirit of power which has been called the "American emancipation of muscle." This also, and not only her immense natural resources of raw material, is part of the secret of American success in this age of steel, of her triumphant march towards industrial supremacy in the twentieth century.

As to the future, it is proverbially unsafe to prophesy. But this at least seems clear, that even in the unlikely event of no new supplies of ore being



Wigan Coal and Iron Co.

STEEL WORKS: FOURTEEN-INCH ROLLING MILL.

discovered, the furnaces of the world could be kept going on known deposits for a long time to come. Improved transportation facilities, and new methods of smelting ores at present considered refractory or unpayable, would also increase the ore-resources known to be available.

INDEX

Adamas, 110
Agricola, 191, 240, 242, 300
Alaska, 100 etc.
Albertus Magnus, 111
Amalgamation process, 79, 81, 174, 180, 201
Amsterdam, 147
Angeles, Los, 31
Anthracite, 253
Argonauts, 3
Arrastra, 18, 20, 173
Augustin method, 214
" Auld Reekie," 239
Australian mines, 44, etc.

Bahia, 118
Ballarat, 46–51
Bank-blasting, 91
" Banket " reefs, 62, etc.
Barberton, 69
Barnato, Barney, 133
Barrel process, 193
Barrow Hæmatite Co., 322
Bateas, 118
Bearing system (coal), 237
Bebulo, 160
Bendigo, 50
Berezovsk, 28
Beroldingen, F. von, 228
Bessemer, 304, 327, 328
Big Blue Lead, 39
" Black sands," 65
Bloomeries, 297, 300
" Blue ground," 128, 129, 130, 139
" Blue rock," 65
Bolckow and Vaughan, 310
Bonanza Creek, 102
Bords, 244
Borghis, Hortensio, 148
Brazilian gold-mines, 21
Brilliants, 148
Brown coal, 253
" Bruting," 147
Buckland River, 49
Buddles, 41, 83
Bultfontein, 125, 126

Calamites, 224
Calcination, 324
Camara, Manuel, 23
Cannel, 253
Cardan, Jerome, 111
Cascalho, 21, 117, 118, 119
Catalan forge, 299
Catas, 21
Cavello, Loyola, 30
Cazo process, 180
Cellini, Benvenuto, 111
Cerro de Pasco Co., 180
— — Potosi, 181
Chilean gold-mines, 20
Chlorination process, 86
Choke-damp, 240
Clanny's lamp, 250, 285
Coal, discovery, 222; origin, 331

223; carboniferous age, 224, etc.; history of mining, 230, etc.; Roman use, 231; "sea-coal," 233, 234; growth of trade, 235; development of methods, 242, etc.; principal coal-fields of the world, 252, etc.; coal-getting methods, 273, etc.; "lay-out," 277; coal-cutting machines, 281; coal winding, 283, 284; safety lamps, 285, 286; disasters in mines, 287, etc.; exhaustion of coal-fields, 291
Coal-fields of Saxony, 232, 264; Belgium, 232, 263; Scotland, 232, 261; North England, 233, 254; South Wales, 240, 259; Shropshire, 245; Cumberland, 246, 255; Great Northern, 254; North Midland, 256; Yorkshire and Derbyshire, 256; Lancashire, 257; South Staffordshire, 258, 279; France, 262; Saarbrucken, 264; Silesia, 265; Austria, 265; Russia, 265; Spain, 266; Nova Scotia, 266; United States, 267, etc.; Texas, 269; India, 270; China, 271; Japan, 272; New South Wales, 272
Coal-seams, Worm, 232; Top Hard, 256; Barnsley Thick Bed, 256; Clod, 256; Black Shale, 256; Silkstone, 256; Ardwick, 257; Mountain Mine, 257; Ince, 257; Wigan, 257; Bradford, 258; Thick Coal, 259; Coalbrookdale, 259; Black Vein, 260; Jewel, 261; Diamond, 261; Beefie, 261; Splint, 261, 262; Drumgray, 262; Kiltongue, 262; Virtuewell, 262; Main, 262; Ell, 262; Flénu, 263; Shansi, 271
Cog and rung gin, 244
Collieries:
Abercarn, 288
Arley, 257
Cannel, 257
Cannock Chase, 259
Hartley, 287
Lowther, 246
Maypole, 288
Monkwearmouth, 254
Oaks, 288
Pendleton, 258
Pretoria, 288
Whitehaven, 246, 255
Colliery explosions, 247, 248, 250, 287, etc.
Colorado, 44
Columbus, 14, 15
Combination-pan, 202
Comstock Lode, 42, etc.; 198, etc.
Coniferæ, 226
Conquistadores, 14, etc.; 167
Coolgardie, 96, 98
Copiapo, 185, 186
Cort, Henry, 303
Cortes, 16, 30
Cuba, 167
Cullinan, T. M., 142
Cupellation, 219

Damascus steel, 299
Dannemora, 312
Darby, Abraham, 248, 303
Davy, Sir Humphry, 251
Dawson, Dr. G. M., 101
De Beers, 125
—— Company, 133, etc.
Diamantina, 117
Diamond fields and mines:
Africa, South, 121, etc.

Diamond fields and mines—*cont.*
America, South, 115
Borneo, 115
Colesberg Kopje, 126, 128
Dutoitspan, 136
Golconda, 112, 113
India, 110, 112
Jagersfontein, 136
Kimberley, 126, 128
Koffyfontein, 142
Minas Geraes, 116
Orange Free State, 126
Premier, 142
Roberts-Victor, 142
South Africa, 121, etc.
,, America, 115
Vaal, 122, 123
Voorspoed, 142
Wesselton, 136
Diamonds, origin, 108; artificial, 108; in ancient literature, 109; ancient mines, 112; South American discoveries, 116; fluctuations in price, 120; South African mines, 121, etc.; history of Kimberley, 128; collapse of pits, 129; co-operation, 131; Cecil Rhodes, 133; the Premier Mine, 142, etc.; refraction in diamonds, 146; cutting, splitting, and polishing, 147, etc.
Diamonds, famous:
Cullinan, 143, 144, 150, 151, 155
Darya-i-Nur, 154
Excelsior, 155
Great Mogul, 115, 148
Great Table, 154
Jubilee, 155
Koh-i-noor, 115, 148, 151, 152
Nizam, 154
Diamonds, famous—*cont.*
Orloff, 152, 153
Porter Rhodes, 155
Regent (or *Pitt*), 153
Sancy, 154
Star of South Africa, 122, 154
Star of the South, 154
Stewart, 155
Tiffany, 155
Victoria, 155
Diodorus, 8, 9, 158
Domesday Book, 232
Dredging (gold), 92, etc.
Dundas, 97
Dutoitspan, 124, 136

Ekaterinburg, 28
Eldorado Creek, 102
Electrolytic process, 88, 215

Fahlbands, 194
Fire-damp, 240, 286
Fluming, 37
"Forty-niners," 34, 41
Free-milling system, 40
Freiberg process, 193

Garimpeiros, 116
Gellivara, 312
Goaf (or gob), 278
Gold, universal desire for, 2; commercial uses, 3, 4; occurrence in nature, 4; dawn of mining, 6, etc.; New World mining, 14; Cortes and Pizarro, 16, etc.; Brazilian mines, 21, etc.; Russian mines, 28, 29; California, 30; the gold-rush of 1849, 33; placer-mining, 37; hydraulicking, 39, 88, etc.; quartz-mining, 40; American mines, 41, etc.; Australian discoveries, 45; world's pro-

duction, 51; South African gold, 61, etc.; the Gold Coast, 72, 73; modern methods, 74, etc.; later gold-booms, 96, etc.
Gold-fields:
Africa, South, 61, etc.
„ West, 72
Australia, 45, etc.
Brazil, 21–27
California, 30, etc.
Chile, 19
Colorado, 44
Coolgardie, 96
Coromandel, 98
De Kaap, 69, 70
Geelong, 71, 72
Gwanda reefs, 71
Gympie, 53
Hannan's Belt, 98
Hungary, 12
India, 6, 56, 60
Kalgoorlie, 98, 99
Kolar, 57, etc.
Mexico, 16
Minas Geraes, 23, 27
Mysore, 56
Ophir, 6, 70
Peru, 18
Russia, 28, 29
Samos, 8
Siberia, 8
South Africa, 61, etc.
Spain, 10, 12
Tarkwa reef, 72
Tartessus, 7
Witwatersrand, 62, 63, 69
Yukon, 100, etc.
Gold-mines:
Buckland River, 49
Comstock, 42
Crown Reef, 66, 67
Geelong, 71, 72
Geldenhuis, 66, 67
Gold-mines—*cont.*
Globe and Phœnix, 71
Great Bonanza, 42
Great Boulder, 100
Lazarus, 50
Main Reef, 65
Meyer and Charlton, 68
Mount Morgan, 52, etc.
Selukwe and Bonsor, 71
Sheba, 70
Simmer and Jack, 67, 77
South Star, 51
Treadwell, 104
Victoria, 50
Worcester, 88
"Golden Mile" (Kalgoorlie), 97
Grao Mogul, 119
Grizzleys, 78
Guadalcanal, 160, 163
Gupiarras, 117
Gurgulho, 117

Hæmatite, 307
Holing coal, 280
Hydraulicking, 39, 88, etc.

"I.D.B." (illicit diamond-buying), 137
Iberian mines, 10, etc.
Incas, 176, 177
Iron, characteristics, 292, 293; ancient use of, 294; primitive smelting, 294, 295; development of steel, 298; forging and casting, 299, 300, 301; blast-furnaces, 302, 325, etc.; puddling and rolling, 303; distribution of ores, 308, etc.; methods of mining, 321, etc.; calcination, 324; progress in America, 327, etc.
Iron deposits:
America, North, 316

Iron deposits—*cont.*
Australia, 319
Bilbao, 315
Britain, 297, 308
Canada, 316
Cleveland, 309, 322, 327
Cumberland, 309, 322
Elba, 296
Forest of Dean, 308
France, 311
Germany, 311
India, 319
Lake Superior, 317, 323
Lancashire, 309, 322
Spain, 296, 315
Sweden, 312
United States, 316, etc.

JAGERSFONTEIN, 136
Jason, 5
Jiggers, 82
Johannesburg, 62, etc.
Jones, Edward, 132

KALGOORLIE, 101, 102, 103
Kara, 28
Kaye, Dr., 239
Kimberley, 96, 126, etc.
Kind-Chaudron method, 275
Kirving, 280
Klondike, 101, 102, 103
Kolar gold-fields, 57, etc.
Krupp, 315

LAKE-ORES (iron), 313, etc.
Lama, 173
Lavaderos, 20, 175
" Lay-out," 277
Leadville, 44
Leland, 239, 240
Lepidodendra, 225, 229
Lignite, 259
Limonite, 308
Linkenbach Table, 84
Linschoten, van, 112
Lixiviation process, 214, etc.
Lobo, Bernard, 116
" Long Tom," the, 36
" Long-wall " work (coal), 277

MACARTHUR-FORREST process, 87
McIver, Mr. Randall, 70
Macquarie River, 46, 49
Magistral, 174
Magnetite, 307
Marsant lamp, 286
Melbourne, 47
Menes, 5, 158
Meteorites, 308
Mexican process (silver): *see* Patio
Minette iron-ore, 311
Molinos, 172
Morgan brothers, 53
Motolinia, Fray, 16
Mueseler lamp, 286
" Mustard " gold, 99

NEILSON, J. B., 304
Newcastle-on-Tyne, 233, 240, 242
Newcomen's engine, 248
Newminster Abbey, 233
Nuggets of gold, 47

OBUASSI, 73
Ophir, 6, 7, 70
Ore-crushing, 66, 79
— dressing, 82
— roasting, 41, 85, 204

PAN-AMALGAMATION process, 201, 203
Patera process, 214
Patio process (silver), 172, etc.
Pillar-work (coal), 277
" Pipes " (diamonds), 137

Pit-and-adit system (coal), 236
Pit-bank, 284
Pizarro, 18, 19, 176
Placer-mining, 37
Plattner process, 86
Pliny, 160, 296
Plooy, Cornelius de, 125
Pniel, 122, 123
Poetsch method, 275
Polybius, 161
Potosi, 177
— Chimney, 200
Prinsloo, Joachim, 142
Putting, 282
Pyrites, 308

QUARTZ-MINING, 40

RAND gold-mines, 61, etc.
Reese River process, 203
Rhodes, Cecil, 133, 134, 135
Rhodesia, 70
Rock-drills, 77
Rodrigo, Antonio, 21
Rose diamonds, 148
Russell, Mr. E. H., 215

SAFETY Lamps, 249, etc.; 285
San Francisco, 32
Savery's engine, 245, 247
Sea-coal, 233, 234, 238, 239
Shakespeare, 238
Siberian mines, 8, etc.
Siemens, Dr., 88
Sierra Nevada mines, 197, etc.
Sigillaria, 226
Silver, etymology, 156; properties, 156; distribution, 157; ores, 157; early history, 158, etc.; mediæval mines, 162, etc.; fluctuations in value, 165; the New World mines, 167, etc.; Mexico, 168, etc.; Mexican process, 172, etc.; Peru, 176, etc.; Chile, 183; European mines, 187, etc.; North American mines, 197, etc.; the Comstock, 198, etc.; Australian mines, 216, etc.
Silver mines and fields:
Arizona, 212, etc.
Australia, 216, etc.
Austria, 162, 188
Banat district, 189
Barrier Range, 216
Bebulo, 160
Broken Hill, 216, etc.
Caracoles, 185
Chanaracillo, 185
Chile, 183
Colorado, 209
Comstock lode, 198, etc.
Consolidated Virginia, 200
Constantina, 162
Erzgebirge, 190, 192
Eureka Consolidated, 205
Exchequer, 200, 209
Flagstaff, 209
Freiberg lode, 191, 193
Germany, 163, 190, etc.
Gold Hill, 203
Golden Chariot, 207
Great Laxey, 196
Guston, 211
Hartz district, 193
Hiendelaencina, 188
Huanchaca, 183
Iberia, 160, 187
Ida Elmore, 207
Jaroso vein, 188
"K. K." mine, 206
Kolivan mines, 195
Kongsberg, 194
Laurium, 159
Leadville, 209, etc.
Mexico, 168

Silver mines and fields—*cont.*
Nerchinsk, 195
Norway, 194
Peru, 176, etc.
Pioche, 207
Portugalete, 183
Potosi, 177, 181, etc.
Prospect Mountain, 205
Pulacayo, 183
Rammelsberg, 163
Reese River, 203
Rosario vein, 171
Ruby Hill, 205
Russia, 195
Santa Rosa, 179
Savage, 200
Saxony, 164
Siberia, 195
Silver Hill, 205
Silver Star, 209
Spitalberg lode, 189
Utah, 208
White Pine, 205
Yankee Girl, 212
Zalamea, 162
Slime, 80
Smelting (silver), 176; (iron) 297, 299
Spitzkasten, 83
Sponge gold, 100
Staiths, 238
Stamps and stamping mills, 79, 80, 184, 201
Stephens, Brunton, 54
Stephenson, George, 250
Stetefeldt furnace, 203, 204
Stigmaria, 226
Stopes, 76
Strabo, 161
Sturtevant, Simon, 302
Sump-holes, 95
Sutro, Adolph, 43
Sutter, Johan, 31

"TABLE" of a diamond, 148, 149, 150
Tailings, 40, 66, 92
Tavernier, J. B., 113, 114, 151, 154
Tina process, 185
Toledo steel, 299
Transvaal, 61, 63, 69
Trapiche, 20
Trommels, 82, 83, 93
Trompe, 299
Tubbing, 244, 274, 275
Tyne, the, 233, etc.

VALENCIANA, 170
Vanners, 83, 85
Ventilation, 245, 276, 284
Veta Madre, 169
— de la Biscayna, 169
— de Colquinia, 177
— de Pariarica, 177
Virginia City, 198
Voetsk, 28

WASHOE process, 201
Wernher, Beit & Co., 67
Wessels, J. J., 136
Whim-gin, 244
Williams, Mr. G. F., 135
Wills, Captain, 143, 144
Winstanley and Barker coal-cutter, 281
Witwatersrand, 62, 63, 69

"YELLOW GROUND," 126
Yukon gold-field, 100, etc.

ZIERVOGEL process, 214
Zimbabwe, 71
Zwickau, 232, 264

PRINTED BY
HAZELL, WATSON AND VINEY, LD.,
LONDON AND AYLESBURY.

THIS BOOK IS DUE ON THE LAST DATE STAMPED BELOW

AN INITIAL FINE OF 25 CENTS WILL BE ASSESSED FOR FAILURE TO RETURN THIS BOOK ON THE DATE DUE. THE PENALTY WILL INCREASE TO 50 CENTS ON THE FOURTH DAY AND TO $1.00 ON THE SEVENTH DAY OVERDUE.

OCT 31 1932

DEC 23 1932

JAN 5 1933

AUG 18 1933

OCT 13 1933

APR 4 1934

4/30

1May51BB

OCT 3 1941M

1May51BB

19Apr'51LU

6Nov51LU

5Fe'53ML

FEB 4 1953 LU

15Dec'55TF

DEC 8 1955 LU

17Aug'57PT

REC'D LD

SEP 5 1957

LD 21–50m-8,'32

YD 04054